Review of fishing practices which have been adapted in commercial fisheries around the world in order to help mitigate the sector's contribution to climate change

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Executive Summary

In response to mounting concern around climate change, the Scottish Government has set targets to achieve net zero by 2045, and through the Future Fisheries Management (FFM) Strategy 2020-2030 to support the fishing industry `to take action to mitigate the sector's climate change related impacts. The overarching aim of the FFM Strategy is to ensure that fishing is environmentally, economically and socially sustainable. The transition to net zero will be challenging for the fishing sector, which relies heavily on fossil fuels, but also presents an opportunity to create a positive impact. This study aimed to identify interventions undertaken in Scotland, the United Kingdom (UK) and European Union (EU) (2010 – 2021) to reduce climate related impacts from the marine wild capture fisheries sector. This information can help shape best practice within the fishing industry, while building more resilient businesses and supply chains that support sustainable, local and rural economies.

A comprehensive literature review identified specific interventions taken in Scotland, the UK and EU to reduce the climate related impacts of the marine wild capture fisheries sector. The outputs of the literature review were complemented with a series of stakeholder interviews to collate information and opinions of direct experiences, including any challenges (perceived or experienced) and opportunities with regards to reducing fisheries impacts on climate change. By comparing interventions aimed at reducing the impact of fisheries on climate change in Scotland, with those elsewhere, it was possible to identify key gaps in the Scottish approach. These results were synthesised to provide recommendations for actions that could be most effective in Scotland at reducing the climate impacts associated with marine wild capture fisheries.

This synthesis will help to elucidate the policy options available to reduce climate change impacts while ensuring business viability, sustainability and resilience. Building an understanding of the way the Scottish fisheries sector impacts the climate will help deliver the best results for the Scottish marine environment, its fishing industry and its fishing communities. Altogether, this represents the first step in producing an evidence-base in support of a 'climate-smart' fishing industry, understanding the avenues by which fisheries and fishers can prepare for a net zero target.

The literature review identified eight key areas where potential changes in fisheries practices could be implemented. These are:

1. **Fossil fuel consumption**; efforts to reduce consumption and associated greenhouse gas (GHG) emission from fishing vessels.
2. **Alternative energy**; Cleaner energy supply for fish and shellfish processing.
3. **Selectivity**; the use of more selective and efficient methods of fishing.
4. **Local Markets;** better use of local markets, reducing food miles and associated GHG emissions.
5. **Reducing waste**; efforts to reduce waste/gear loss, thereby reducing marine litter and GHG emissions.
6. **Refrigerants**; measures taken to reduce the contribution of refrigerants to GHG emissions.
7. **Stock resilience**; measures to improve stock resilience to climate change.
8. **Consumer behaviour**; efforts to change consumer behaviour.

Scotland and its fisheries are involved in many interventions that could reduce the sector's impact on climate change, but the results of these actions are often not recorded, reported or publicly available. Enhancing coherence in target setting for data collection, and greater transparency in data collection, analysis and reporting will help demonstrate to policy makers, the industry and the public the benefits of progressive change while also increasing policy makers understanding of quantifiable outcomes.

In addition, demonstrating the value and efficacy of such changes could help drive a shift in consumer behaviour, boosting local consumption of Scottish seafood and help strengthen the positive feedback loop between production and consumption.

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1 Introduction

1.1 Background

1.1.1 The Climate Emergency

In 2021, the Intergovernmental Panel on Climate Change (IPCC) published a special report on the impact of a global warming at 1.5 °C above preindustrial levels. It sets out the likely consequences of the current levels of global warming as well as those of a 1.5-degree global warming (IPCC, 2018). Global warming was assessed as likely to be between 0.75 °C and 0.99 °C in the 2006-2015 decade compared to the 1850-1900 mean temperature, with a rise of about 0.2 °C per decade.

In 2020, the UK communicated its new Nationally Determined Contribution (NDC) under the Paris Agreement to the United Nations Framework Convention on Climate Change (UNFCCC). The NDC commits the UK to reducing economy-wide GHG emissions by at least 68 % by 2030, compared to 1990 levels. The Paris Agreement also commits signatories to achieving net zero by 2050.

1.1.2 The Climate Change Act

The Climate Change Act[1], as amended in 2019, commits the UK to net zero by 2050. The original act, passed in 2008, committed the UK to an 80 % reduction of GHG emissions by 2050, compared to 1990 levels. In 2019, the Climate Change Act 2008 (2050 Target Amendment) Order 2019 was passed which increased the UK's commitment to a 100 % reduction in emissions by 2050.

1.1.3 Scotland's Commitment

Additional to the UK target, the Scottish Government has set a more ambitious net zero target by 2045 with interim targets for reductions of 75 % by 2030 and 90 % by 2040. This is one of the most ambitious statutory targets of any country globally, going beyond what

[1] Climate Change Act 2008 (legislation.gov.uk)

the Intergovernmental Panel on Climate Change (IPCC) said is required worldwide to limit warming to 1.5 °C .

To meet Scotland's targets, a rapid transformation across all sectors of our economy and society is targeted. Key actions to support this transition include:

- A reduction in GHG emissions through a 'Just Transition' to a net zero economy and society, ensuring the journey is fair and creates a better future for everyone – regardless of location, status or nature of their work;
- Supporting decarbonisation in the public sector;
- Engaging with business and industry on decarbonisation;
- Engaging the public and encouraging individuals to move towards low carbon living;
- Supporting communities to tackle climate change; and
- Delivering a Just Transition, by working with communities, business, industry and the people of Scotland to plan for our net zero future.

The UK Fisheries Act 2020 sets out a commitment for governments to develop policy to deliver the 'Climate Change' objective to mitigate and adapt to climate change. These commitments will mean that industries in UK (and peoples' daily behaviour) will have to undergo significant changes in order to meet these targets.

Scotland's Marine Assessment, published in 2020[2], summarises the latest evidence of the currently observed changes to the marine environment and how these may likely develop in the future.

1.1.4 Fishing practices in Scotland in the context of climate change

The fishing industry has an important part to play in reducing emissions and helping to create a low carbon economy with clean, green jobs. The transition to net zero will no doubt be challenging for the fishing sector, but also presents an opportunity to make a

[2] Marine Scotland Assessment Climate Change: https://marine.gov.scot/sma/assessment-theme/climate-change

positive impact by adjusting practices, and growing Scottish businesses and supply chains in a sustainable way to create good, sustainable jobs.

In December 2020, the Scottish Government launched Scotland's Fisheries Management Strategy 2020-2030 (FFM Strategy)[3], which sets out a vision for Scotland to be a world class fishing nation, delivering responsible and sustainable fisheries management which provides access to a high protein, low carbon food. The Strategy is the first Scottish fisheries policy instrument to bring climate change into the fisheries management conversations and to give it the urgent tone that it requires. Specifically, the Strategy commits to taking action to understand and mitigate the impacts of climate change on our seas, supporting delivery of the Scottish Government's net zero targets, including by reducing vessel emissions and encouraging shorter supply chains. In addition, it will support and encourage sustainable waste management in Scottish fleets, growing the circular economy and reducing marine litter.

The FFM Strategy builds on a growing recognition that fisheries management must operate on an ecosystem scale, in order to find the balance between environment, economic and social outcomes. Considering ecosystem effects, fisheries have always been challenged by large background fluctuations in environmental conditions. In respect to such environmental impacts, the long-term perspective in the development of the FFM Strategy calls for more coherent environmental management that allow stocks to recover from abrupt or long-term environmental changes, while "*tackling the global climate emergency and limiting temperate rise to 1.5°C*".

The overarching aim of the FFM Strategy is to ensure that fishing is environmentally, economically and socially sustainable. It explores how the delicate balance between environment, economic and social outcomes can be achieved. Ecosystem studies show that the main impacts from fishing are seabed abrasion and removal of species. However, there is also a need to balance mitigation measures against the socio-economic benefits that fishing brings. In response to the issues identified in the Strategy there is a clear need

[3] Future fisheries: management strategy - 2020 to 2030 - gov.scot (www.gov.scot)

to secure a robust evidence base which will increase understanding of what actions and interventions are needed in order to mitigate the climate related impacts that result from fisheries and associated industries.

1.2 Aims and Objectives

This literature review aims to drive improvements in Scotland's fisheries sector, by providing the information necessary to facilitate successful and efficient reductions in GHG emissions and other climate change related sectoral impacts. Specifically, interventions taken in Scotland, the UK and EU (2010 – 2021) will be identified, in an effort to reduce the climate related impacts of the marine wild capture fisheries sector. At the same time, these interventions should aim to maintain or improve the sector's viability, sustainability and resilience.

The project aims to answer the following questions:

- In the past five to 10 years, what actions have been taken in Scottish fisheries (include known trials where access to ongoing research can be obtained) to reduce GHG emissions from the sector and to mitigate other fisheries associated climate change impacts. What gaps can be identified, for example and are there other actions which could have been taken?
- In the past five to 10 years, what actions to mitigate the contribution to climate change have been taken in the UK and internationally in relation to fisheries which may be relevant to Scotland (predominantly trawl and creel fisheries, focused on shellfish, whitefish and pelagic species).

The project will draw on a literature review of such interventions coupled with a series of stakeholders' interviews to collate information and opinions of direct experiences, any challenges (perceived or experienced) and opportunities with regards to reducing fisheries impacts on climate change.

The Scottish fishing fleet is made up of Scottish-based vessels registered to a port in Scotland and which are licensed and administered by a Scottish district. The number of active Scottish based vessels was 2,088 vessels in 2020. The Scottish fleet is dominated by vessels that are ten metres and under in length, accounting for 75 % of the Scottish fleet in 2020. The ten metre and under fleet mostly fish using creels (sometimes called pots). Creels catch some shellfish species such as crabs, lobsters and Nephrops, but other species like scallops are predominantly caught through dredging and Nephrops is also caught through trawling.

In the over ten metre vessels category, 71 % mainly targeted shellfish within 2020, with 21 % targeting demersal species (such as cod, haddock, whiting, monk fish). Only 22 vessels mainly targeted pelagic species (such as blue whiting, herring and mackerel) (Scottish Sea Fisheries Statistics 2020 (www.gov.scot)).

Taking account of the complexity of the Scottish fishing fleet[4], the findings will establish the suitability of interventions to reduce the effects of climate change in a Scottish context, including any information where available, on lessons learned from interventions that have been less effective. In addition, comparing interventions aimed at reducing the impact of fisheries on climate change in Scotland, with those from elsewhere, it will be possible to identify gaps in the approach taken in Scotland. These results will then be synthesised to provide recommendations for actions that could be most effective in Scotland at reducing the climate impacts associated with marine wild capture fisheries.

This will help to elucidate the policy options available to reduce these impacts while ensuring businesses continue to be viable, sustainable and resilient. Driving understanding of the way our fisheries sector impacts the climate will help deliver the best possible results for the Scottish marine environment, its fishing industry and fishing communities. Altogether, this represents the first step in producing an evidence-base in support of a ‘climate-smart’ fishing industry, understanding the avenues by which fisheries and fishers can prepare for a net zero target.

[4] Scottish Sea Fisheries Statistics 2020 (www.gov.scot)

2 Literature Review

2.1 Methodology

A systematic literature review was conducted. Literature searches were conducted in Google Scholar, allowing access to both peer-reviewed and grey literature. All searches were carried out between December 2021 and January 2022. The search strings used during the literature review are available in Appendix A.

Searches used Boolean logic to combine terms relating to the fisheries sector and its associated climate change related impacts. Literature searches were restricted to the time period 20102010 to 2021. This produced 210,560 search results in total. Titles of the first 30 results from each search were scanned (n=1820), and abstracts were read for those papers still considered relevant (n=302). Papers found to contain information relating to actions ongoing or taken in Scottish, UK and European fisheries to reduce GHG emissions from the sector and/or to mitigate other fisheries associated climate change impacts were extracted and saved using open-source reference management software Zotero.

Screening by title, abstract and/or executive summary, to exclude references not relevant to the scope of work, included the following exclusion criteria:

- The subject of the publication was not related to the fisheries and/or processing sector;
- Geographic scope (i.e., not based in Scotland, UK or Europe[5]); and
- The publication did not contain actions that had been taken to reduce GHG emissions, or wider impacts of climate change.

The remaining publications were considered to be of direct relevance to this review and were examined in full to extract the relevant information and to highlight additional sources of information for inclusion (Appendix B). The literature selection process is depicted in

[5] The geographic scope was limited by the resources available; therefore, the focus was on those areas most closely linked to Scotland, including Scotland itself, the wider UK, and other countries within Europe.

Figure 2.1. In addition, references were retained if the publication addressed, or was relevant to mechanisms, by which the fisheries sector could reduce GHG emissions and/or to mitigate other fisheries associated climate change impacts.

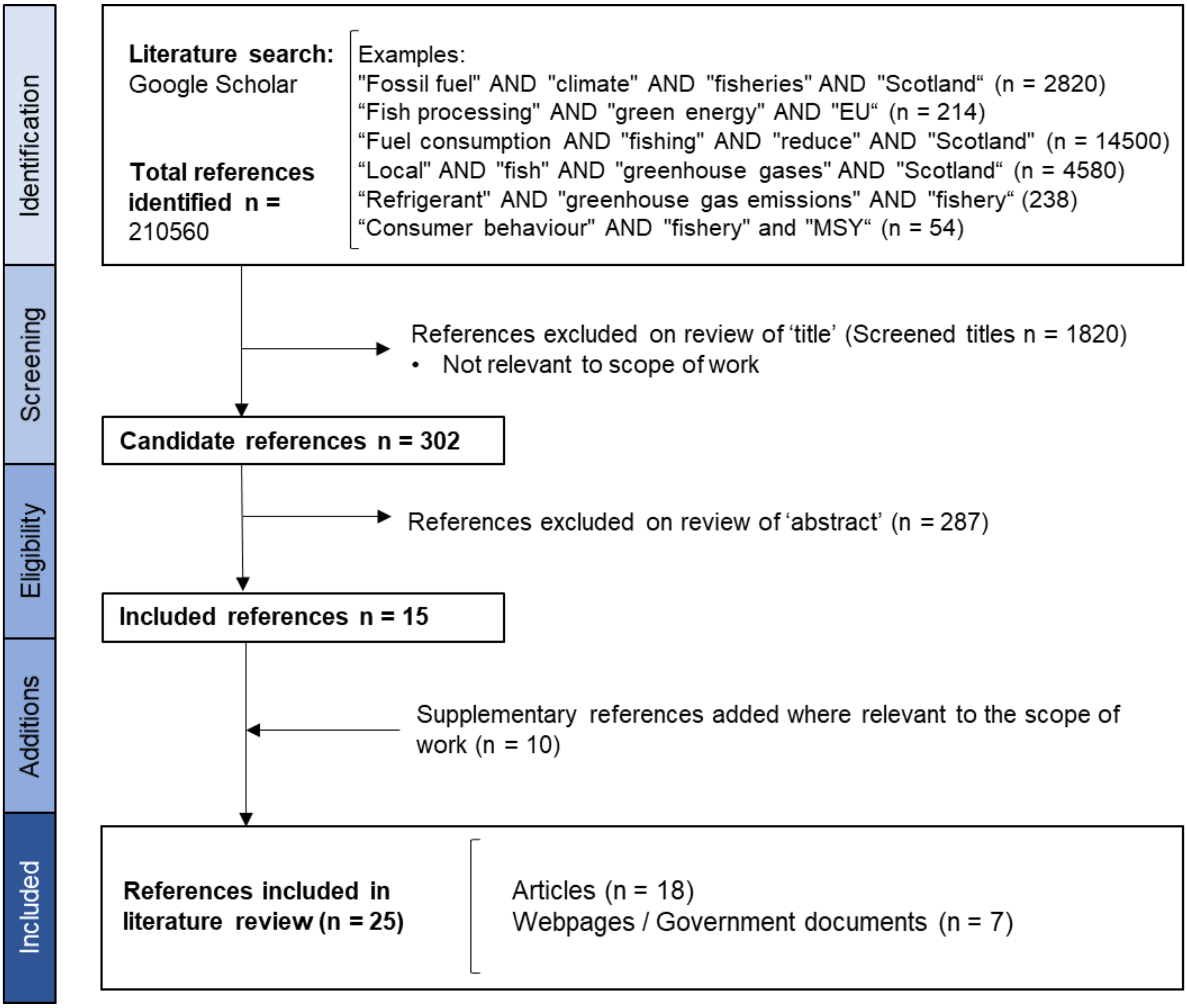

Figure 2.1 Flow diagram of the literature search and selection process.

Supplementary references were included within the literature review where there was relevance to the project scope, this included a reference from 2022. In order to address the project's aims (set out in Section 1.2), the literature review was focused on Scotland, the UK and Europe. The 25 references included within this study are focused on examples of actions that have been taken to reduce the fisheries sector’s impact on climate change within nine European countries (seven EU member states), and within the four UK home nation (Figure 2.2). When looking at these actions, broken down by geographical region (Figure 2.2), the Netherlands was found to have the greatest number of examples (n=3) after England and Scotland (n=7). The cause for the high number of examples within the literature for Scotland and England is likely a factor of the search criteria, which explicitly included both “UK” and “Scotland”.

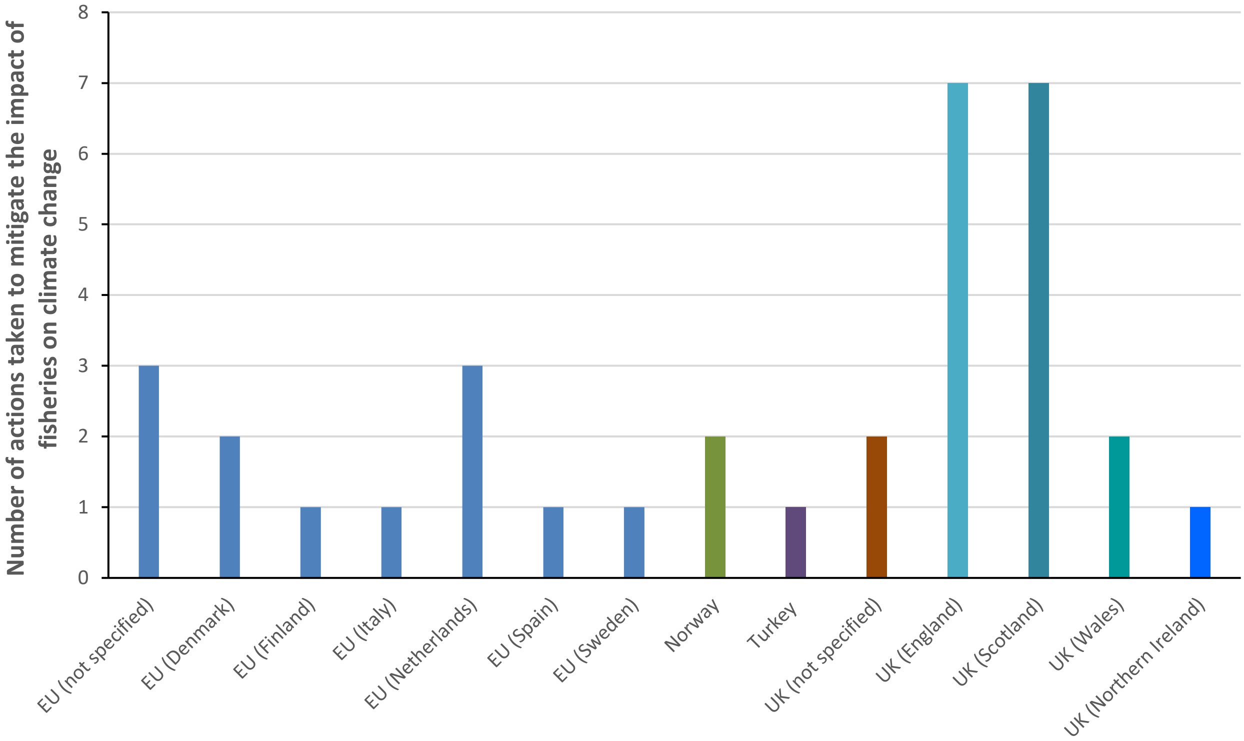

Figure 2.2 Bar chart showing the geographical location of actions taken to mitigate the impact of fisheries on climate change (some articles included multiple actions, sometimes in different countries)

2.2 Actions to mitigate the fishing sector’s impact on climate change (2010 – 2021)

The wider capture fisheries sector, including fishing, postharvest processing as well as product distribution is highly energy dependent, focused primarily on the use of fossil fuels (Muir, 2015). For example, Parker et al. (2018) estimates that in 2011, global fisheries consumed around 40 billion litres of fuel and emitted around 179 million tonnes of CO_2e, or around 4 % of the emissions of global food production in that year. By 2016, fishing vessel emissions had risen to 207 million tonnes of CO_2e (Greer et al., 2019), which is around 0.6 % of global CO_2e emissions that year[6]. However, it is not only fishing vessels, and direct fuel consumption, that contribute to the sectors climate change related impacts. There are a number of other factors within the fishing and seafood industries which contribute to climate change impacts; for example, GHG emissions from seafood transport, processing and storage, or wider ecosystem impacts associated with unsustainable harvest rates, poor selectivity, and habitat damage caused by bottom contacting towed gear.

There is paucity of information in the primary and secondary (i.e., grey) literature of businesses taking actions to mitigate the impacts of fisheries on climate change, predominantly due to such actions being taken for economic, instead of environmental, reasons. For the majority of the fishing sector, where there is an economic incentive to make a change (e.g., reduce fuel use, upgrade engines, introduce new fishing gears), or respond to changing legislation (e.g., decisions prohibiting specific refrigerants), then businesses will react to these stimuli and adapt appropriately to ensure smooth and profitable business operations. In fisheries operations, adaptations such as these, which have the direct goal of improving the businesses profitability, take place continually (known as ‘technological creep’, Ricci et al., 2022). However, where such actions are taken, these are predominantly in relation to reducing cost rather as *per se* changes in the role of fishing activities on climate change. Although the indirect result of such changes may be a reduction in GHG or reduced ecosystem impacts, this is not the ultimate reason for the change or response.

The lack of information within the primary and secondary literature on actions taken by the industry that may reduce their impact on climate change, may also be associated with a relative absence of reporting by the fishing industry in peer reviewed or public fora. For the majority of fishing companies, changes in working practices, including those that enhance

[6] Global CO_2e emissions in 2016 were 32,940,650,079 tonnes; The Data World Bank: https://data.worldbank.org/indicator/EN.ATM.CO2E.KT

their ability to compete with the wider industry (and which may indirectly reduce fisheries role in intensifying climate change), will likely be classed as commercially sensitive. It is then highly unlikely that such actions are published, with such information remaining within the confines of the business. Such information will likely only become available when it is not deemed commercially sensitive, usually when such business practices are well known in the industry or do not enhance the businesses' competitive economic activities.

In terms of fisheries management actions, the link between management practices and resilience[7] of the stocks to climate change 'threats' is often indirect. This is due to changes in management being principally carried out to ensure the sustainability of the industry and fishery, in reaction to short term changes in stock biomass or fishing pressure. Such changes may help to build resilience to the effects of climate change, but also means that any improvement in management can be effectively labelled as an 'action' to build resilience, though is not directly imposed as such. In this respect, there are a myriad of changes that have been undertaken within fisheries management (within Scotland, the UK and wider EU) that may have (or had) indirect effects on the resilience of the respective stocks. Very few examples were returned by the literature review using the pre-determined search strings, however this aspect would benefit from being pursued as a separate piece of work.

To examine and provide a detailed synopsis of the potential actions, taken by the industry and in terms of fisheries management, we focus on eight broad categories of potential change in fisheries. These describe the mechanisms by which GHG emission reductions and wider fisheries induced climate change impacts mitigation can occur. Within each of the eight categories, examples of actions taken to mitigate the impacts of climate change are discussed, along with a description of the actions that are being undertaken in Scotland compared to the wider UK and EU, including possible evidence gaps. These eight categories are set out below:

[7] Resilience can be understood as the ability of a fish stock to recover from a shock, in this case one caused by extreme weather events and changing climate exacerbated by anthropogenic climate change.

- **Fossil fuel consumption;** efforts to reduce fossil fuel consumption and associated GHG emission from fishing vessels.
- **Alternative energy;** Cleaner energy supply for fish and shellfish processing.
- **Selectivity;** the use of more selective and efficient methods of fishing to either:
  - Reduce fishing effort (time at sea); or
  - Reduce fuel consumption while fishing.
- **Local Markets;** better use of local markets for local produces, reducing food miles and associated GHG emissions.
- **Reducing waste;** efforts to reduce waste/gear loss, thereby reducing marine litter and GHG emissions.
- **Refrigerants;** measures taken to reduce the contribution of refrigerants to GHG emissions.
- **Stock resilience;** measures to improve stock resilience to climate change.
- **Consumer behaviour;** efforts to change consumer behaviour to either:
  - Focus on species that are fished at MSY; or
  - Reduce food miles and associated GHG emissions.

To examine and understand the role of such actions in structuring the Scottish fishing industry, the learnings from the literature review have been utilised to develop and enhance a stakeholder questionnaire (Section 3.2.2). This has been to ensure that responses from Scottish stakeholder's address both the gaps in the literature as well as gaps in the understanding of such actions in Scotland. In addition, by building the questionnaire in a stepwise approach this has served to ground truth initial findings and set these more firmly within the Scottish context.

2.2.1 Fossil fuel consumption

There are a range of actions that fishers can take to reduce fishing vessel fossil fuel consumption and related GHG emissions (Table 2.1). The focus of this section is to describe the physical changes that have been made to fishing vessels in order to increase their fuel efficiency. These changes can be lumped into improving the efficiency of propulsion systems or improving hydrodynamics (e.g., changes to engines, gear boxes, propellers, hull design or antifouling systems). We discuss with examples such changes, and the role of such changes in impacting fuel efficiency.

Table 2.1 Table showing a range of measures and actions that fishers can take to reduce fishing vessel fossil fuel consumption and related GHG emissions. (Source: He et al., 2018)

ITEM	ACTION	FUEL SAVING	
		Low	*High*
HULL RELATED			
Bulbous bow	Retro-fit installation	5%	15%
Hull appendages	Reduce/smooth/align appendages	2%	5%
PROPULSION RELATED			
Vessel speed	Reduction	5%	20–30%
Engine	Replacement with new	7%	20%
Engine	Correct design/installation including exhaust		4%
Gearbox & propeller	Replacement	5%	15%
Propeller nozzle/duct	Install	0%	15 – 20%
Trim & weight	Correction	0%	5%
Fuel meter	Install & keep records		
NON-PROPULSION RELATED			
Hydraulics	Upgrade pumps and controls		
Refrigeration	Upgrade compressors & pumps Improve insulation		
Heating/cooling, electrical & lighting	Utilise waste heat. Improve insulation		
Parasitic loads such as pumps & motors	Upgrade controls, switch off all above	0.5%	1.5%
Operational awareness	Improve by training & record keeping		<10%

Propulsion systems (Engines)

Replacing older less efficient engines, to improve the fuel efficiency of fishing vessels and reduce GHG emissions, has been widely used across the UK and the EU. For example, Owen et al. (2019) found that between 2014 – 2020 the EU's European Maritime and Fisheries Fund (EMFF) funded seven engine upgrades on fishing vessels in England to this end. These projects cost £7,842 on average, and where results were reported, led to around 15 to 30 % (30 to 70 litres) reduction in fuel consumption per week. Such upgrades and change in fuel consumption is equivalent to an annual reduction of 4.81 kg CO_2e[8]

[8] CO_2e = Carbon dioxide equivalent (i.e., emissions of all greenhouse gases with the equivalent global warming potential of CO_2)

emissions for every £1 of EMFF funding (Owen et al., 2019). Such projects, where engines are upgraded, are relatively easy to implement and have a low initial cost. Based on the examples of fishing vessels in England, these predominantly only result in about 90p saved (social cost of carbon[9]) for every £1 spent over the expected 20-year life span of the new engine (Owen et al., 2019).

Unfortunately, from the publicly available information, it is not possible to determine additional information regarding the vessels that received engine upgrades through EMFF funding (e.g., vessel size or metier). In addition, Owen et al. (2019) report that "*the lack of data collection by individual project beneficiaries has made it difficult to quantify progress towards…the targets set by the MMO as a condition of funding*", targets that include emissions and fuel use reductions.

It is clear from Scottish government grants such as the "Fishing vessel energy improvements and re-engining grant"[10] and EMFF project descriptions (made publicly available through the transparency initiative[11]) that similar re-engining and upgrading has taken place in Scotland. However, the results of these projects, and others like them, have not been made publicly available. This represents a major gap in information and understanding around the actions taken to reduce GHG emissions from the fisheries sector. It is therefore important that such data is made publicly available in order to enhance the understanding of the role of such actions in reducing GHG emissions from the Scottish fishing industry.

[9] Social cost of carbon, given as £12.76 per tonne of CO_2e - Updated short-term traded carbon values used for UK policy appraisal (2018): https://www.gov.uk/government/publications/updated-short-term-traded-carbon-values-used-for-uk-policy-appraisal-2018

[10] Fishing vessel energy improvements and re-engining grant: how to apply: https://www.gov.scot/publications/fishing-vessel-energy-improvements-and-re-engining-grant-how-to-apply/

[11] European Maritime and Fisheries Fund: beneficiaries: https://www.gov.scot/publications/european-maritime-and-fisheries-fund-beneficiaries/

Propulsion systems (gearbox and propeller)

One way to measure and improve propulsion efficiency upgrades is a Bollard pull test[12], which determines the static pull that a vessel is able to employ in operating conditions (El Zaalik et al., 2015). These have been used within the EU to investigate thrust under different modification scenarios, in order to optimise gearing and achieve maximum efficiency (Notti and Sala 2012; Notti et al., 2014). During trials, where a reduction gear box and ducted propeller have been used, fuel consumption has been reduced by up to 15 % (Notti and Sala, 2012). Such modifications, which can be used to improve vessel fuel efficiency, are able to be applied to both contemporary and older vessels.

It is also clear from EMFF project descriptions, made publicly available through the transparency initiative[13], that propulsion system (i.e., gearbox and propeller) upgrades have taken place in Scotland. However, these projects are few in number and their results, and information on other similar projects, have not been made publicly available. Again, as with understanding changes in engines within the Scottish fleet, this represents a major gap in information on the actions taken to reduce GHG emissions from the fisheries sector.

Hull design

Modification to improve hydrodynamics, and therefore fuel efficiency, is another route that can be taken to reduce GHG emissions from fishing vessels. Generally, this involves either modification to vessel hull design (e.g., the addition of a bulbous bow) or improved antifouling. Changes to the hull design of existing vessels are often relatively costly and inefficient compared to engine refits (Table 2.1), with examples of bulbous bow retrofits from England showing saving of around 1.67 kg CO_2e for every £1 spent (Owen et al., 2019).

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12 To measure the pulling capacity of a vessel, a bollard pull test is used to classify tugs on their towing ability. Experimentally, the test is carried out by using a bollard to anchor a vessel to the pier. Then, without slack in the connecting link, the vessel is required to propel itself at maximum thrust.

13 European Maritime and Fisheries Fund: beneficiaries: https://www.gov.scot/publications/european-maritime-and-fisheries-fund-beneficiaries/ (last accessed: 24/01/2022)

Szelangiewicz et al. (2021) found that the addition of a bulbous bow can increase vessel resistance, fuel use and GHG emissions, but at higher speeds this trend is reversed. Therefore, a careful examination of vessel speeds during steaming, deploying gear and during fishing would need to be carried out to determine if such a retrofit would be beneficial to the fishing vessel in question.

Hull length to width ratio also plays a major role in hull resistance, and in general increasing this ratio (i.e., greater length vs width) will reduce resistance (He et al., 2018). Theoretically, the power required for a 12 m vessel could be reduced by 21 % if fishing capacity and width remained equal, but vessel length increased to 14 m (He et al., 2018; Tourret and Pinon, 2008). In the same way, increasing the length of a 17.5 m vessel to 21.5 m would decrease the overall power required by 27 % (He et al., 2018; Tourret and Pinon, 2008). This would suggest that policy and decision makers looking to reduce fishing vessel GHG emissions should incentivise vessels with an optimised length to width ratio. Yet, due to UK and Scottish licencing systems that rely on length-based fisheries management, there is a threshold that keeps vessels below 10 m (Davies et al., 2018). This has resulted in vessels increasing their fishing capacity, partly by increasing width, while remaining below 10 m in length.

A number of existing management measures may also inadvertently disincentivise fuel efficiency, and obscure actions taken to reduce GHG emissions within the fisheries sector. Hull length to width ratio plays a major role in hull resistance, and in general increasing this ratio (i.e., greater length versus width) will reduce resistance (He et al., 2018) and therefore could act as a *barrier* to reducing fisheries climate related impacts. Yet, due to UK and Scottish licencing systems, that rely on length-based fisheries management, there is currently an incentive to keep vessels below 10 m (Davies et al., 2018). This has resulted in vessels increasing their fishing capacity, partly by increasing width, while remaining below 10 m in length.

Such vessel designs have been associated with vessels being developed for the specific species they are targeting, the suitability of the grounds and their utility; these vessels are not *per se* designed to produce as low GHG emissions as possible. In this respect, some older vessels have been adapted as a result of fishing technology advances, operational safety, and following full industry consultation where commercial fishing licences were simplified and streamlined to below 10 m and over 10 m in 2017.

With new vessel construction industry naturally looking into operating and design efficiencies, and as new technology is adopted, particularly driven by fuel price and environmental concerns, policy makers should be looking at ways to encourage adoption of those designs/ technologies which have been developed with the purpose of reducing GHG emissions within the fisheries sector but must remain mindful of balancing opportunity and fleet capacity within effort limits.

Antifouling

Increasing hull surface roughness, associated with biofouling, increases the friction resistance of vessels (Hakim et al., 2019). Such increased friction then necessitates the need for more power to move a vessel, resulting in an overall increase in fuel consumption (Hakim et al., 2019; Nama and Akter, 2021). Although antifouling systems are generally inexpensive, compared with other modifications, their operational lifespan is relatively short (Owen et al., 2019; Nama and Akter, 2021). For example, one year following hull cleaning, the high growth of biofouling can result in fuel consumption increasing by 88 % (Nama and Akter, 2021). This serves to highlight the importance of effective biofouling systems if GHG emissions from fishing vessels are to be reduced.

The results and existence of projects aimed at optimising fishing vessel antifouling to reduce GHG emissions within Scotland are not publicly available. It is widely understood that antifouling is ongoing within the fishing fleet, but there is a paucity of specific information expounding how these actions reduce GHG emissions from the fisheries sector.

2.2.2 Alternative energy

Fisheries processing, including food safe storage, requires large amounts of energy. Therefore, if climate change related impacts of the fisheries sector are to be mitigated, there is a need to identify actions that can be taken to optimise energy use and minimise carbon emissions during fish and shellfish processing. Below we provide a synopsis of the range of actions uncovered by the literature review that are being undertaken in UK and elsewhere in Europe to reduce and optimise energy use, which has focused on efficiency in the regulation of energy while also undertaking further use of potential waste from fish processing.

A smart energy cluster model for the Milford Haven industrial site in Wales was published in 2020. This set out how to manage energy use more efficiently, with the push to switch to a predominantly solar energy supply (Alzahrani et al., 2020; Petri et al., 2020). The proposed system would provide cost advantages to local industries, while also providing energy to the fish processing industry and local community. In fact, estimates were that energy supply would only be expected to dip below demand during winter months (Alzahrani et al., 2020; Petri et al., 2020), leading to a reliable and near self-sufficient energy system. Reduction of the carbon intensity of the electricity grid due to interventions in the energy sector (i.e., the increasing generation from renewable sources) should lead to reduced GHG emissions from the fisheries processing sector.

With an estimated 35 % of globally harvested fish and shellfish currently wasted (FAO, 2020), utilising this waste stream represents a major opportunity to reduce the fisheries sector's carbon footprint. Examples of reducing waste could include turning waste to feed for aquaculture. In Finland, there is ongoing work turning fish waste (from processing) into biodiesel. Biodiesel can be considered close to carbon neutral because fish absorb CO_2 in life equivalent to the CO_2 released when fuel is burned. Mikkola and Randell (2016) report that the site in Finland produces around 400 litres[14] of biodiesel per day, which is mainly used for business operations and powering local buses. Despite this, Mikkola and Randell (2006) noted that production had not been scaled up commercially due to high taxation on biodiesel in line with that of diesel,

[14] 400 litres of carbon neutral fuel as a replacement for diesel will reduce the CO_2 emissions from fossil fuels by around 1 tonne, because 1 litre of diesel produces around 2.67kg of CO_2 (Valsecchi et al., 2009).

Another innovative solution designed to improve energy efficiency comes from Aquapri, an aquaculture and fish processing plant in Denmark. Aquapri makes use of a bespoke ventilation system, implemented as part of a larger energy improvement project in operation since 2015. This cost £523,270[15] and was self-funded by the plant (Solberg and Brem, 2016). Despite this large initial outlay, including taking nine months to complete, the return on investment was expected to take 2.5 years (Solberg and Brem, 2016).

2.2.3 Selectivity

There are several ways in which increasing the selectivity of fishing gear can act to ameliorate fisheries induced climate change impacts. Below we examine the effect of selectivity in impacting time at sea and fuel consumption while fishing, and show that significant GHG emission reductions can be made with changes to fishing gear.

Reduced fishing effort (time at sea)

Trawls will often discharge their catch on deck, re-deploy their gear, and then tow as the previous catch is graded and stowed. Therefore, increased selectivity is unlikely to affect the time they spend at sea.

For static gear, where the catch is generally sorted as the gear is brought on board, a cleaner catch (i.e., less bycatch) may mean reduced time sorting, with a shorter time between hauls leading to less time at sea overall. However, for stocks fished in UK waters where the potential catch is not limited by a quota system (e.g., crab, lobster), fishers may simply spend the same amount of time at sea, but deploy more gear due to time efficiency savings. Therefore, the overall impact on emissions reductions is unknown. EMFF funded projects in England, aimed at improving pot selectivity, found that unwanted catches with (new) more selective pots were reduced by 10-15 %, with no reported decrease in landings (Owen et al., 2019). It is unclear what effect this had on the fisher's time at sea and fuel consumption.

[15] Note: All currency conversions were made on www1.oanda.com. In this case the currency conversion was made with rate at 01/01/2015 - the beginning of the year the processing plant was opened

Real time reporting of data and information between vessels about areas with a high abundance of unwanted species and sizes (hotspots) may be a potential way of supplementing selective fishing gear. Such methods are being examined within the EU project ØBJ FISK (funded within the INTERREG IV project). The ØBJ FISK project investigated how real time reporting, of areas with a high abundance of non-target species, could be used to facilitate shorter area closures (Eliasen and Bichel, 2016). Closures of around 3 weeks were suggested to replace longer term closures currently in place when bycatch ratios cross certain thresholds (Eliasen and Bichel, 2016). Such ability to understand areas of high discard species would allow vessels to continue fishing, whilst avoiding those areas with a high abundance of non-target species. Within Scotland a similar trial was conducted to test a bycatch avoidance APP (Marshall et al., 2021), however the trial has not led to any conclusive results. In both cases the pathway to reduced GHG emissions is opaque, however if vessels are able to have lower fuel intensity (i.e., amount of catch landed for each litre of fuel used – the lower the intensity the higher rate of landings per fuel used) by targeting areas of low bycatch, this may reduce overall GHG emissions.

Reduced fuel consumption while fishing

The fuel consumption of fishing vessels while actively fishing is often considered to be the largest contributor to GHG emissions emitted by fisheries, including those within Scotland. For example, Sandison et al. (2021) found fuel use accounted for nearly 96 % of emissions for the Scottish pelagic fleet. Because one of the biggest financial costs to the industry is also fuel use, there are numerous interconnected benefits to improving fuel efficiency. Efficiency incentivises innovation in vessel design and engine improvement (discussed above, section 2.2.1), but also gear design. Indeed, major net manufacturers have indicated that they have been substantially engaged with their customers to improve net design efficiency, including minimising weight and improving hydrodynamics (Sandison et al., 2021) to promote more fuel-efficient fishing practices.

While towing trawl gear, generally two thirds of the vessel’s energy consumption will be related to the additional effort required to tow the gear (He et al., 2018). In fact, just increasing mesh size or using finer diameter twine can lead to reductions in drag (He et al., 2018), and can reduce overall fuel consumption by approximately 18 % (e.g., Parente et al., 2008; Priour, 2009). In 2011, a trawl system in the Danish Baltic Sea cod fishery, utilising larger mesh and lighter gear was developed to optimise trawl gear to reduce drag. This system exchanged 12 mm steel trawl warps for 10 mm Dyneema®[16], while the whole body of the net, except the codend, was made of 1.4 mm Dyneema® (Hansen and Tørring, 2012). Hansen and Tørring (2012), found that the results of this Dyneema® trawl system included a 40 % reduction in fuel consumption (per kg of cod caught), increased catch per unit effort, and reduced bottom contact and ecological impact (Hansen and Tørring, 2012).

For bottom contacting gears, such as the trawl system trialled in Denmark, reducing bottom contact can have a big effect on fuel efficiency. In England, the Western Fish Producers Organisation (WFPO) recently conducted a trial with Sumwings, which replaced traditional otter doors on a beam trawler out of Brixham, in the south east of England. These new doors were trialled by the WFPO following similar trials in Holland and Belgium that reported 30 % cuts to fuel use (Caslake, 2022). Importantly, results from the WFPO trial found a 42 % reduction in fuel use (with ongoing use, the average reported fuel saving was approximately 30 %) and reduced interaction with the seabed, leading to a 69 % drop in discards of benthic species (Caslake, 2022). Decreased interaction with the seafloor (by up to 84 %) also doubled the expected lifespan of the fishing gear (Caslake, 2022).

A similar example, from the Turkish sea snail beam trawl fishery in the Black Sea, found that improving sledge design reduces resistance, seabed interaction and fuel consumption (Kaykaç et al., 2017). This change was easy and relatively cheap to implement. Pulse trawling was originally trialled to replace the tickler chain beam trawl in the Dutch flatfish fishery, ostensibly aimed at reducing discards and fuel consumption (Van Marlen et al., 2014). This innovation generated fewer fish discards (~57 %) lowered fuel consumption (37 – 49 %), and increased profit for fishermen despite lower landings (Van Marlen et al., 2014). However, pulse trawling has been banned in the UK and EU over concerns of “negative social and environmental impacts” (Kraan et al., 2020), including issues of

[16] Fishing gear manufacturer company website: https://www.dsm.com/dyneema/en_GB/home.html

animal welfare (De Haan et al., 2016) and the injury and mortality of non-target species (Southerland et al., 2016).

Although the examples discussed above highlight the actions that can and are being taken to adapt fishing gear to reduce drag and therefore GHG emissions, there are no examples of such gear change from within Scotland.

2.2.4 Local markets

The impacts of the COVID-19 pandemic and EU-exit have been felt heavily in supply chains across all sectors, including fisheries and seafood. Issues within the supply chain, including a widespread loss of income and additional regulations, have led to difficulties obtaining supplies, logistical disruptions and demand fluctuations (Sengupta at al., 2021). Mitchell et al. (2020) reports a short-term shift towards local markets and production in the food industry following COVID-19, but predict that this change will be short lived. For the UK, this is because the seafood market is heavily reliant on trade with the EU and globally.

However, the impact of EU-exit poses significant issues to the success of the market chain supplying seafood to the UK. The exit of the UK from the EU has the potential to push those EU suppliers marketing their goods within the UK towards greater use of their local markets, avoiding the potential increased tariffs and restrictions associated with exporting goods to the UK (Symes and Phillipson, 2019). This may have potential benefits to the degree of GHG emissions associated with the transport of goods from the EU to the UK, but may also lead to increased loss of goods. This could be due to longer transport routes between the EU and the UK (due to with increased administrative burden and therefore more issues with the transport of goods into the UK). A compounding factor could be an increase in produce being landed in local markets but not being sold, or being sold for a much lower premium (because of the high quantity available) – both will lead to such fisheries showing higher rates of fuel intensity.

There is a trade deficit for fish products in the UK, where consumption has been significantly higher than production by around 366,500 tonnes in 2016, since at least 2000 (Carpenter and Owen, 2018). As a result, without reducing the trade deficit, there is a limit to the food miles that can be cut by increasing the use of local markets. Therefore, within the UK further use of local markets will not be sufficient to cover the seafood needs of the country. In this respect, relying solely on domestic production for Scottish fish consumption is unlikely. Nevertheless, understanding what is being done to make use of local markets for the sale of fish and shellfish could help reduce the GHG emissions associated with their transport. This could form a good starting point for planning how Scotland can make better and more local use of its fisheries produce, which is significant.

2.2.5 Reducing waste

There are two key mechanisms by which decreasing the loss of fishing gear/waste in general can act to reduce the impacts of fisheries induced climate change impacts. These two mechanisms are:

- Functional fishing gear loss, leading to increased direct GHG emissions associated with replacement fishing gear production and transport; and
- Abandoned Lost and Otherwise Discarded Fishing Gear (ALDFG), leading to ghost fishing and a decrease in ecosystem resilience to the effects of climate change.

Reduced loss of functional fishing gear

Although not directly examined within the literature, reducing the rate at which functional fishing gear (i.e., gears that are in use) is lost may indirectly reduce potential GHG emissions. This is due to the potential reduction in the carbon footprint associated with the longer use of fishing gear if not lost. This also could result in lower total gear production (as new gears do not need to be manufactured as readily), including reducing the need for transport of such gears from the manufacturer to the end user. Although not examined within the literature, there are a number of different projects that reduce the number of lost gears, including through retrieval, management space use and gear design to reduce loss.

In Norway the Directorate of Fisheries conducts an annual retrieval project for the recovery of lost gill nets; fishermen can report the location of their fishing nets when the gear is set to improve the chances of recovery (Langedal et al., 2020; Mengo, 2017). Clear gear identification also discourages damaged gear being abandoned or dumped at sea. The project has been successful, with a reported increase of lost gear recovery, but also less incidental damage of gear, as location reporting allows nearby vessels to avoid set gear, minimising the chance of causing damage (Langedal et al., 2020; Mengo, 2017).

A similar location reporting system is being trialled in the Netherlands, where a mobile phone app is used to record the location of gillnets when set, so that other vessels can avoid them. This reduces gear conflict (e.g., mobile gears towing over and moving static gears) and encourages fishermen to leave gaps between nets with enough space for the trawlers to pass. The reported results have been positive and the loss of nets has “declined substantially” since the mobile phone app introduction (Mengo, 2017).

As stated above (section 2.2.3), within the UK, the Sumwing trial by the WFPO has reduced trawl interaction with the seafloor (by up to 84 %). This is due to the gear’s smaller footprint than a traditional beam trawl, due to the single foot setup in the centre of the beam (Caslake, 2022). This effectively doubles the expected lifespan of the fishing gear (Caslake, 2022) and therefore reduces the likely increased GHG emissions associated with the manufacture of new gears.

It is understood that the Scottish Government are supporting efforts within the European Committee for Standardization’s Standard for Circular Design of Fishing Gear. This is developing standards that are aimed at improving the circular design on fishing gear, which could reduce the GHG emissions associated with gear production. Additionally, there are efforts being made within OSPAR (to which the Scottish government contributes) to link extended producer responsibility efforts to actions in the updates on the Regional Action Plan for Marine Litter (Morag Campbell, Pers. Comm). These efforts are ongoing but the mechanism by which they could reduce GHG emissions from fishing gear production is indirect and unlikely to be realised for some time.

Despite the range of projects being undertaken to increase the lifetime of fishing gears, there is no clear evidence in the literature of actions being undertaken (similar to those above) to reduce gear loss in Scotland. This represents a major gap in information and understanding around the actions taken within Scotland to reduce GHG emissions from the fisheries sector.

Reduced ALDFG

The effect of ALDFG on climate change and its related impacts is generally indirect and is mainly through the impacts of ghost fishing (i.e., the capture and mortality of aquatic fauna in ALDFG). Unfortunately, this mortality is not taken into account in fisheries management plans, so can disrupt stock recovery, potentially having indirect effects on GHG emissions in the fleet, e.g., if stock biomass is depleted then catch per unit effort is generally sub-optimal (i.e., more time, and therefore fuel, is required to catch the same volume of fish).

Between 2010 and 2021 there are many examples of actions taken in Scottish, UK and EU fisheries to incentivise best practice in fishing gear and plastics disposal, which thereby reduce the likelihood that fishers will intentionally abandon plastics or gear at sea (Feary et al., 2020). For example, the Net Regeneration scheme run by Odyssey Innovation[17] in the South of England collects end-of-life fishing gear for recycling, while in Scotland the Fishing for Litter project, implemented in 2005 and coordinated by KIMO UK[18], involves 285 vessels and 20 ports participating in the removal and processing of marine litter. At the time of writing (February, 2022), fishing for litter had removed over 1,800 tonnes of rubbish from the ocean, and the project is ongoing in Scotland and across Europe, currently funded in Scotland by Marine Scotland (OSPAR, 2020).

Norway introduced a strategy in 2013 whereby fishing vessels could dispose of waste and marine litter in port without paying an extra fee. Instead, a fixed waste disposal fee is included in the port charge (Mengo, 2017). Sweden implemented a similar 'No-Special-Fee' system, where commercial fishermen can pay a set port fee, allowing the disposal of waste in port. Likewise, the 'Keep the Sea Clean' project in Bohuslän (Sweden) facilitates the collection and recycling of fishing gear and litter caught whilst fishing (Mengo, 2017). Meanwhile, pilot projects have been conducted in Spain to improve waste management on

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[17] Company website Odyssey Innovation: https://www.odysseyinnovation.com/net-regeneration-scheme

[18] https://fishingforlitter.org/

vessels and in harbours. Within this system waste containers were installed on vessels, and recycling points in fishing and navigational docks, facilitating easy participation in best practice gear disposal; as a result, fishers were more likely to do so (Mengo 2017).

In fact, the EU's Port Reception Facilities Directive sets out aims to increase the availability of port reception facilities, in an attempt to mitigate the illegal discharge of waste from ships, including fishing vessels. This was transposed into domestic UK legislation by the "*Merchant Shipping (Port Waste Reception Facilities) Regulations 2003 to prevent waste produced on board ships from getting into the sea*"[19]. This requires that Scottish ports provide adequate facilities in each port for the disposal of ship generated waste (including fishing gear). This service should be paid for by the vessels calling at the port irrespective of whether or not they use the service. This should, therefore, discourage the illegal dumping of fishing gear at sea. However, no information was provided on the efficacy of this legislation.

Although the Fishing for Litter project in Scotland facilitates the cost neutral removal of marine litter, which can include end-of-life fishing gear, very little is known about the volume of fishing gear run through the scheme, and once removed, where it ends up (at present the majority is likely to be sent to landfill, as there is little capacity in the EU to recycle non-clean fishing gears). In Addition, during the extensive literature review examples of the Port Reception Facilities Directive[20] being implemented within the UK and EU were not identified. This represents a gap in the available literature and it would be useful to better understand how this statutory instrument is being implemented to advance best practice fishing gear and marine litter disposal. No information is available in the literature on other projects or attempts to incentivise best practice in fishing gear disposal.

[19] Marine litter issues, impacts and actions https://www.gov.scot/publications/marine-litter-issues-impacts-actions/pages/6/

[20] Directive (EU) 2019/883 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019L0883&rid=1

2.2.6 Stock resilience

Climate change combines long-term trends, due to changes in ecosystems, and short-term incidents, due to extreme weather conditions (Bastardie et al., 2022). As a result, adaptation to short-term climatic shocks, which may have demographic impacts as well as distributional impacts to stocks, within fisheries management requires implementing systems that contribute to promoting both long-term ecological and short-term economic resilience (Bastardie et al., 2022). In this respect, fish stocks that are well managed (i.e., above biomass reference points and exploited below mortality reference points) can be more resilient to climate related issues (e.g., extreme weather conditions) (Bastardie et al., 2022). Importantly, management must also include an understanding of the stock distribution. Fish populations will move according to environmental changes, so what may appear to be stock decline could be shifts in stock distribution associated with environmental change (Rijnsdorp, et.al., 2009).

There are many actions that fisheries managers can take to bolster the resilience of stocks to the impacts of climate change. The focus of this section is then to highlight examples of where improved resilience has been achieved, and some of the mechanisms used to improve resilience.

Measures to improve stock resilience through harvest strategies are driven at a regulatory and policy level and the aim is always to reach Maximum Sustainable Yield (MSY[21]) within a stock. Commercial fish stocks in the waters around Scotland (Figure 2.3) have shown positive progress towards this goal in recent years. For example, in 2020 an estimated 69 % of fish stocks of commercial interest to Scotland were fished at sustainable levels. The figure comes from the SSFI (Sustainability of Fish Stocks Indicator[22]) which uses the historical ICES estimates of fish mortality (F) and spawning stock biomass (SSB)[23] to

[21] The largest average catch or yield that can continuously be taken from a stock under existing environmental conditions" (ICES, 2012)

[22] National Indicator Performance | National Performance Framework, Scottish Government

[23] "Spawning stock biomass. Total weight of all sexually mature fish in the stock" (ICES, 2012)

determine whether F < F(msy)[24] and/or SSB > MSY B(trigger)[25] for the key commercial stocks of interest to Scotland. The 69 % number for the most recent year (2020) is the overall proportion of these stocks for which F and SSB have been estimated to be within MSY bounds for that year. This represents an increase of 3 % from 2019 and 35 % from 2000. The percentage fished sustainably in 2020 is the highest level recorded since this data collection began (1991) and demonstrates the ongoing recovery of the commercial fish stocks. All years of data are revised every time the series of indicators is updated, which means that for 2018, a revised figure was released based on the most recent data, and this is now 64 % and not 67 % as previously thought (Scottish Government, National Indicator Performance | Sustainability of Fish Stocks Indicator).

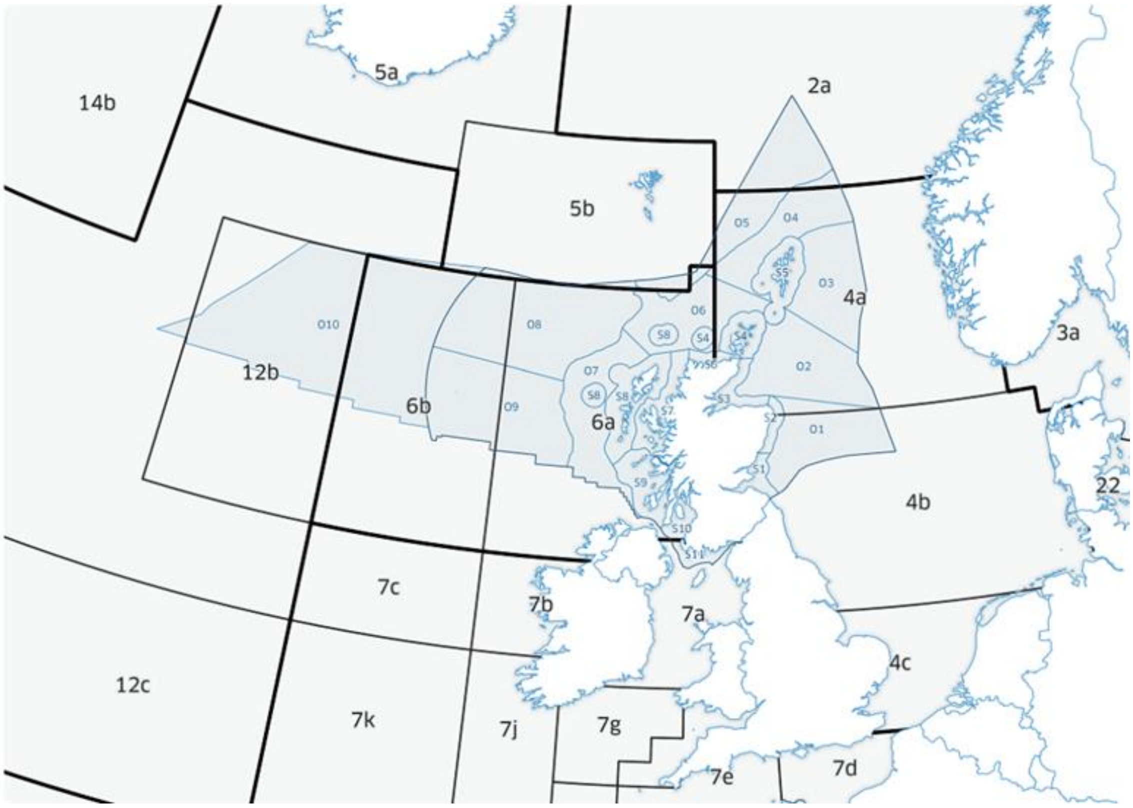

Figure 2.3 Map showing the ICES areas around Scotland, including Scottish Marine Regions and Offshore Marine Regions where fish stocks of commercial importance to Scotland are present (Source: Marine Scotland and ICES)

24 "Fishing mortality consistent with achieving Maximum Sustainable Yield" (ICES, 2012)

25 "Spawning stock biomass (SSB) that results from fishing at FMSY for a long time" (ICES, 2012)

It is clear, from the increasing number of stocks fished sustainably within Scottish waters that progress is being made to bring fisheries in line with practices compatible with an MSY approach. However, there is still work to be done to better manage Scotland's fish stocks and in doing so maximise their resilience to the effects of climate change. This represents an opportunity to further integrate fisheries management with an approach that is consistent with meeting MSY for some stocks, and in doing so bolster their resilience to climate change.

In addition, the searches of this literature review have shown that some of the most valuable fish stocks to Scotland (by total landings value) still have undefined reference points, making effective management more difficult. For example, ling (*Molva molva*) in subareas 3, 4, 6–9, 12, and 14 do not have defined reference points (ICES 2021). This represents a data gap that could undermine efforts to effectively mitigate the effects of climate change on stock resilience through effective management measures.

2.2.7 Refrigerants

The use of specific refrigerants can affect fisheries induced climate change impacts, both through the direct use and then potential release of GHG that are used in refrigerants (i.e., Freon), as well as the fuel (i.e., carbon footprint) of refrigerant units, which can vary substantially in their energy efficiency.

Many refrigerants are over 1000 times more potent as a GHG than carbon dioxide[26]. This potency is known as global warming potential (GWP[27]). Since 2020, fluorinated GHGs with a GWP greater than 2500 have been prohibited in Scotland for use in servicing or refilling refrigeration systems[28]. This is broadly consistent with wider UK and EU regulation.

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26 UN Environment Programme: https://www.unep.org/news-and-stories/story/new-guidelines-air-conditioners-and-refrigerators-set-tackle-climate-change

27 GWP is a measure of the amount of energy (i.e., heat) a unit (e.g., 1kg) of gas will absorb in the atmosphere as a multiple of the energy that would be absorbed by the same mass of CO2. https://www.epa.gov/ghgemissions/understanding-global-warming-potentials

28 Scottish Environmental Protection Agency (SEPA) https://www.sepa.org.uk/regulations/climate-change/fgases-and-ods/

However, there is no other evidence within the literature of actions taken to reduce the contribution of refrigerants to GHG emissions and wider climate related impacts.

In terms of global energy consumption, refrigeration and air-conditioning systems utilised within fisheries (on vessels, as well as in use at landing sites) are associated with high energy use and energy demands (Alzahrani et al., 2020; BIM, 2017; Gephart et al., 2017; Murali et al., 2021). Therefore, improving energy efficiencies in this area could greatly reduce the sectors GHG emissions. According to the UNEP, a shift to best practice cooling technologies globally (across all sectors) could reduce GHG emissions by 38–60 gigatonnes of CO_2 equivalent by 2030[29].

2.2.8 Consumer behaviour

Sustainable food production is increasingly recognised as significant in public perception (Sala et al., 2017), which is driving large-scale shifts in approaches to consumer behaviour (Salmivaara and Lankoski, 2021). However, systems of production and consumption are intertwined and changes towards sustainability in those systems are therefore co-dependent (McMeekin and Southerton, 2012). Shifting consumer focus onto stocks and fisheries that are well managed and fished sustainably (e.g., below F_{MSY} with SSB above B_{MSY}) will incentivise best practice in management and relieve pressure on over-exploited, less resilient stocks.

Eco-labels and initiatives providing consumer information are major mechanisms by which changes to consumer behaviour are facilitated. This is done by providing to the consumer a simple and understandable way to assess a products environmental impact (Sigurdsson et al., 2022). This enables the consumer to make easy distinctions between products that meet verified environmental standards and those that do not (Johnston and Roheim, 2006).

29 UN Environment Programme: https://www.unep.org/news-and-stories/story/new-guidelines-air-conditioners-and-refrigerators-set-tackle-climate-change

The preference of consumer to buy products with an eco-label is becoming increasingly clear. For example, Menozzi et al. (2020) found that within the UK, consumers were willing to pay a £0.64[30] premium for eco-labelled fish, which is higher than the average (£0.59 per kg) across the five European countries investigated. This trend holds in Scotland, where it was found that eco-labelled fish products are less likely to be withdrawn from the shelves than those without accreditation, lasting longer even than products labelled as ‘Scottish’ in origin (Sogn-Grundvåg et al., 2019). For Marine Stewardship Council (MSC) labelled products the risk of being withdrawn from the shelves is 64.7 % lower than non-MSC products (Sogn-Grundvåg et al., 2019).

The MSC is a leading seafood-specific scheme, providing an eco-label for fisheries products which meet set requirements for sustainable fishing[31]. Although this is not directly concerned with climate change (GHG emissions are not considered within the standard), many of the criteria with which fisheries must comply will have an indirect mitigating effect (e.g., selectivity and stock resilience). Indeed, climate change may become more central to the scheme[32], as recent presentations by the MSC have reported that climate change is the most concerning environmental issue to consumers[33].

Actions taken in Scotland to promote eco-labels and to shift consumer behaviour towards more sustainably sourced fish include the promotion of the MSC by Marine Scotland[34]; initiatives to educate the public about seafood sustainability[35]; as well as Seafood Scotland’s strategy for Scotland’s seafood industry, which aims (amongst other things) to

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30 Note: All currency conversions were made on www1.oanda.com. In this case the currency conversion was made with rate at 01/01/2020 - the beginning of the year that the findings were published.

31 Marine Conservation Society: www.msc.org

32 Marine Conservation Society, Sustainable Fisheries https://sustainablefisheries-uw.org/msc-standard-under-review/

33 Marine Conservation Society, The Rise of the Conscious Food Consumer https://www.msc.org/docs/default-source/default-document-library/for-business/rise-of-the-conscious-food-consumer---europe-webinar-slides.pdf?sfvrsn=6c009b42_4

34 Scottish Government, Sea Fisheries https://www.gov.scot/policies/sea-fisheries/fish-stocks/

35 Open Seas https://www.openseas.org.uk/

"*use standards and accreditation to support marketing and improve business performance*"[36].

This builds on other work within the UK and abroad, such as the Marine Conservation Society's Good Fish Guide[37]. The Good Fish Guide provides information to help consumers understand which species and stocks are sustainable and which are not. Species are rated based on stock status, where it was caught or farmed and how. This is a charity funded project and is freely available to the public via their website and an app.

Examples of actions taken to shift consumer behaviour in Scotland are available in the literature and include measures of how effective these shifts have been. Although, there is controversy surrounding the efficacy of some eco-label schemes[38] (Wijen and Chiroleu-Assouline, 2019), and there is limited available information regarding the effect of consumer choices on the associated fisheries GHG emissions.

A complete table of interventions identified during the literature review is provided in Appendix B.

[36] Seafood Scotland http://seafoodscotland.org/wp-content/uploads/2019/05/Changing-Tides-_FINAL_PAGES.pdf

[37] Marine Conservation Society, Good Fish Guide https://www.mcsuk.org/goodfishguide/?gclid=CjwKCAiA6Y2QBhAtEiwAGHybPcj_v_BeH_-IrQyj3hlFcknQDgo_KtpKOFNfNFMf9YuCGsrkP8S1DBoCKfUQAvD_BwE

[38] The Guardian https://www.theguardian.com/environment/2021/jul/26/blue-ticked-off-the-controversy-over-the-msc-fish-ecolabel

3 Stakeholder Engagement

3.1 Introduction

In order to test and validate the findings of the literature review, a round of stakeholder engagement was undertaken, targeting commercial fisheries stakeholders in Scotland. The list of stakeholders contacted as part of this exercise is provided in Appendix C. The online questionnaire which was used for this exercise is available to view separately and has been published as a supporting document[39]. A key aspect of this second phase of work was the development of a targeted questionnaire for commercial fisheries stakeholders, informed by the findings and outputs from the literature review.

3.2 Approach

A phased approach to stakeholder engagement was undertaken to maximise the level of engagement and quality of feedback. In order to achieve this, the following four tasks were completed:

- Preliminary stakeholder contact;
- Submission of targeted questionnaire to stakeholders;
- Direct commercial fisheries stakeholder engagement; and
- Review and analysis of feedback from stakeholders.

3.2.1 Preliminary stakeholder contact

Initial contact with all stakeholders was undertaken via email in tandem with the literature review phase. The primary aim of this exercise was to ensure early engagement, validate contact details of all stakeholders, raise awareness of the project and inform them of the next steps in the process.

[39] Online questionnaire which has been used to engage with the stakeholders in Appendix C https://www.gov.scot/isbn/9781804356623

3.2.2 Submission of targeted questionnaire to stakeholders

A targeted stakeholder engagement questionnaire was developed and submitted to all stakeholders via email. Results from the literature review were incorporated into the development of the questionnaire, to ensure that responses address gaps in understanding and gaps in the literature. In addition, building the questionnaire in a stepwise approach and utilising learning from the literature review, served to ground truth initial findings and set these more firmly within the Scottish context.

3.2.3 Commercial fisheries stakeholder engagement

All stakeholders were contacted by phone (or email in some instances where a phone number was not available), to maximise the response rate to the online questionnaire. This was an opportunity to discuss the respective stakeholders' responses to the questionnaire as well as documenting any other specific feedback in relation to the project topic. All responses were anonymised.

4 Stakeholder Consultation Feedback

Eleven responses were received to the online questionnaire. Two separate email responses were also received, therefore thirteen responses in total. The key findings are presented in the format of the questionnaire and summarised below.

4.1 Physical changes to the fishing vessel to reduce fuel use or to increase fuel efficiency

Of the survey respondents, 69 % who answered this question have made physical changes to their fishing vessel to reduce fuel use or to increase fuel efficiency. This was achieved by replacing the vessel as a whole, replacing parts within the vessels or changing the shape of the vessel. Other changes to the vessel included painting new antifouling[40] onto the vessel, using electric cranes or a full electric deck machinery package, or using lightened trawl gear. For the vast majority of respondents, the reasoning

[40] Antifouling can be defined as the coating, paint, and surface treatment used on a solid (e.g., ship hull) to control or prevent the attachment of unwanted organisms.

behind these changes were due to saving costs and reducing emissions. One respondent stated that such changes were beneficial to reduce both costs and emissions, but also stated that such changes undertaken by the respondent were to ensure the vessel was under IMO requirements.

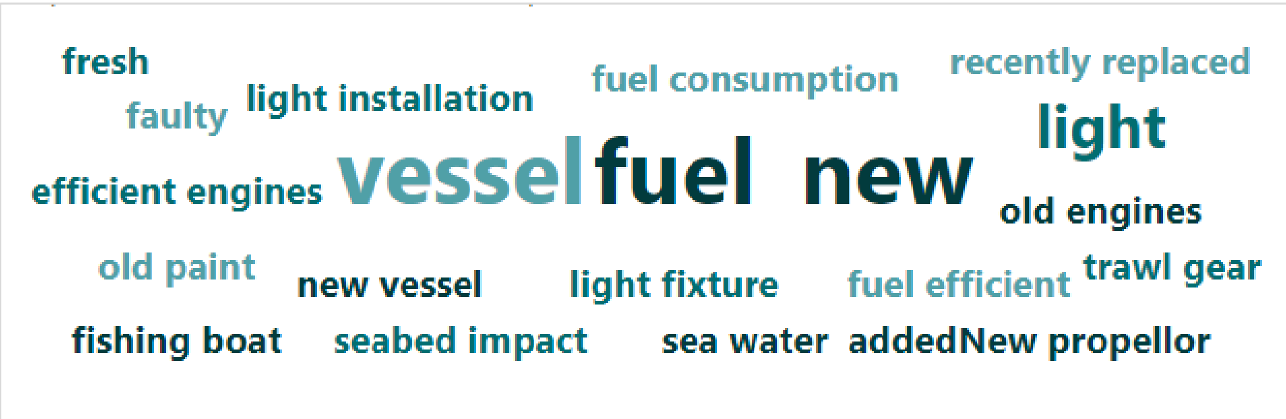

Figure 4.1 An automated word cluster showing the most frequent words respondents used in the survey when asked if they have made physical changes to their fishing vessels which reduced their fuel use or increase fuel efficiency (*This has not influenced the findings from the survey*)

4.2 Alternative fuels

Of the survey respondents, 23 % who answered this question agreed that an initial investment was needed to change to an alternative fuel. However, it was not possible to assess whether these respondents have considered using such fuels. A lower percentage stated that they did not know enough about how to make these changes. Other respondents are looking into the use of alternative fuels by watching developments in other countries or they thought that the concept needed to be further improved and developed to ensure the technology and safety of the crew were up to standard.

4.3 Fishing practices changes to reduce fuel use or increase fuel efficiency

Of the survey respondents, 71 % who answered this question had changed fishing practices to reduce fuel usage or to increase fuel efficiency. There were a range of different approaches stated by respondents: the use of roller clumps[41], targeting higher quality fisheries resources, larger mesh size, the use of pelagic trawl doors, the use of pelagic nets, preplanning best speeds to cruise at, where best to fish, and using smaller nets. Respondents said that making cost savings and reducing emissions were equally important reasons for the change in fishing practices. Specific changes to fishing practices that respondents have made include one respondent who reduced the working week at sea to four days to reduce fuel costs while another respondent purchased a larger boat with a view to reaching the quota quicker and therefore spending less time at sea. These changes had mixed results according to respondents with one reporting a decrease in earnings due to less time at sea and issues with securing the best price at the markets. However, one respondent noted a 40 % reduction in fuel costs over a period of 10 years through using a larger vessel, which led to reduced number of trips required to reach the quota.

Of the 46 % of survey respondents who had not made changes to fishing practices, 23 % said they needed an initial investment to consider making these changes.

4.4 Fish and shellfish processing – how working practices have changed to reduce energy/fuel use

Of the survey respondents, 31 % who answered this question were involved in fish and shellfish processing and all said that they have made changes to their working practices to reduce energy or fuel consumption. Some examples were the use of LED lighting, running the lorry every second day and planning return pickups on every delivery. Again, both saving on costs and reducing emissions were felt to be equally important reasons for the changes. Half of those involved in fish and shellfish processing also had changed their work pattern and had become more efficient throughout. The main reason that respondents had not already made changes was due to the need for initial investment.

[41] A roller clump is used in trawling to reduce interaction with the seabed, therefore reducing drag which can save on fuel

4.5 Changes to reduce waste/gear loss

Of the survey respondents, 54 % who answered this question said that they recycle old gear to smaller vessels or recycle onshore; one fishing vessel company had tried to cut microplastics out of wrapped creels. Respondents said that making cost savings and reducing emissions were equally important reasons for the changes. Respondents indicated that recycling fishing gear and reducing gear loss had increased the lifespan of the fishing gear, with one respondent noting a near doubling of the lifetime of their gear. One respondent referenced net monitoring technologies which could increase the lifespan but noted that large initial investment would be required to implement this specific change. 29 % of respondents stated that there was no need to make any changes to reduce gear loss, suggesting that measures are already in place; 43 % noted a need for initial investment.

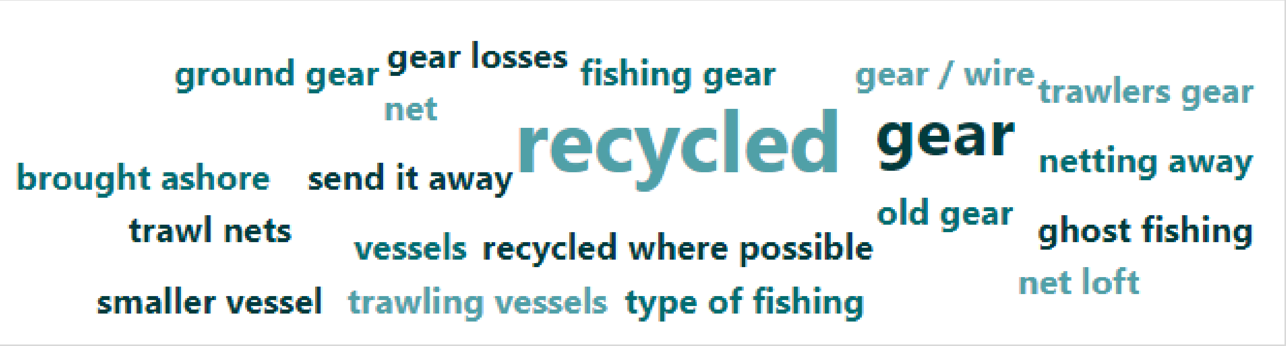

Figure 4.2 An automated word cluster showing the most frequent words respondents used in the survey when asked if they had made changes to reduce waste or gear loss (*<u>This has</u> not influenced the findings from the survey*)

4.6 The use of local markets

Only 20 % of survey respondents who answered this question said that they used the local market. Of those who did not use the local market (80 %), this was predominantly due to the local market not being physically large enough to house the catch from the fleet. One respondent changed to selling to the closest buyer to ensure a decrease in lorry use and thereby fuel costs and reduced emissions. 75 % of respondents stated that the main reason for not making any change was due to the need for initial investment. All respondents said that making cost savings and reducing emissions were equally important reasons for the changes.

4.7 Changes to refrigeration/freezer systems to increase energy efficiency

Of survey respondents, 29 % who answered this question had already made changes to their refrigeration/freezer systems to increase energy efficiency, while the remainder were either looking into it, needed investment or had not changed anything. 60 % of respondents noted that both cost savings and reducing emissions were equally important, while 40 % referenced the need to ensure compliance with regulations. All those who had not made changes stated that initial investment was required to facilitate changes in refrigeration/freezer systems.

4.8 Stock resilience and impacts of climate change on fish stocks

All respondents who answered this question were aware of stock resilience, as well as avoiding fishing within nursery/breeding grounds. Over half believed that there needs to be better use and acquisition of scientific data (for example the use of Remote Electronic Monitoring to gather data at sea), along with flexible management, fishing licenses and better compliance monitoring within the Scottish fishing industry. 23 % were worried about the risk from wind farms to the fishing industry and stocks, with developments such as ScotWind seen as taking away their normal fishing grounds or being planned within spawning/nursery grounds and therefore threatening future stock resilience. Respondents also mentioned further attention to fisherman’s reports, tighter regulations on fishing vessels within the UK and distributing the quota to the younger generation.

Figure 4.3 An automated word cluster showing the most frequent words respondents used in the survey when asked if they are aware of the issues to do with stock resilience and impacts of climate change on fish stocks and if there any specific measures that need to be added (*This has not influenced the findings from the survey)*

4.9 Changes to consumer behaviour to address climate change impacts

The survey respondents were asked if they thought specific measures should be put in place to change consumer behaviour to address climate change impacts. Responses included references to the relatively low carbon footprint of fishing compared to other food industries, and how consumers should be encouraged to eat more fish as it is considered a healthy source of nutrition. One respondent referenced the need for better marketing campaigns on local and national levels to create a greater awareness of the health benefits and where to source locally fished species.

Figure 4.4 An automated word cluster showing the most frequent words respondents used in the survey when asked about whether specific measures should be put in place to change consumer behaviour to address climate change impacts (*This has not influenced the findings from the survey)*

4.10 Other approaches that have been taken or have knowledge of to reduce or mitigate fisheries climate change impacts

The key approach that the survey respondents recommended is using fishing representatives to advise on new developments, for example location of offshore windfarms. One such example given is the Future Fisheries Alliance which set out a blueprint for achieving climate smart fisheries. The survey also establishes that Shetland already upgrade and invest in new fishing boats regularly. Respondents also recommended diversifying inshore fisheries to both trawl and fixed gear. They also emphasized that fisheries have a smaller impact in comparison to other developments, for example the oil and gas industry.

5 Gaps and Recommendations

This section sets out the key gaps and recommendations that have been identified during the literature review. This section is also informed by feedback received in the stakeholder consultation exercise. All gaps identified are in relation to actions taken within Scottish fisheries that could be mitigating the sector's impact on climate change are summarised below.

There are several areas, where there is evidence of initiatives within Scottish fisheries to mitigate the sector's impact on climate change. These have been described above and include actions such as: fishing vessel re-engining, changing propellers and gearboxes, and the prohibition of certain refrigerants (see Section 2.2 above). Despite this, quantitative data and information relating to these initiatives and their efficacy are relatively scant within the public domain. Therefore, it is recommended that for such initiatives, especially those funded through governmental organisations, their effects on mitigating the impacts of climate change should be monitored and outcomes utilised to enhance future policy development within Scotland.

Comparing the range of measures already undertaken within Scotland with those in the UK and EU, there are a range of gaps in the uptake of measures to support the Scottish Government in setting targets for mitigating climate effects on its fisheries. These gaps are listed below, and encompass measures to reduce fossil fuel consumption, the use of alternative fuel, changes in gear selectivity, understanding how local markets may support targets, the reduction of waste, the use and understanding of different refrigerants, the management of Scottish stocks and understanding consumer behaviour. These are all detailed below.

Fossil fuel consumption

Public funding mechanisms, such as the "Fishing vessel energy improvements and re-engining grant"[42] as well as EMFF project descriptions show that re-engining and

[42] Fishing vessel energy improvements and re-engining grant: how to apply: https://www.gov.scot/publications/fishing-vessel-energy-improvements-and-re-engining-grant-how-to-apply/

upgrading has taken place in Scotland. Despite this, it is relatively unclear whether the results from such projects have been collected and collated; certainly, there is no documentation in the public literature and no indication from stakeholder engagement, of the outcomes of such projects. This lack of public presentation of results, especially those funded by the Scottish Government, represents a major gap in information and understanding around the actions taken to reduce GHG emissions from the fisheries sector. It is therefore, important to ensure that such data is rigorously collected and then reported within the public literature to enhance understanding of the role that such actions play in impacting GHG emissions within the Scottish fishing industry.

Alternative fuel

The broad consensus within the available literature is that globally the use of a range of alternative fuels within the shipping industry is relatively new, with inherent logistic and economic difficulties in attaining both the technology needed to utilise such fuels, as well as the fuel, for commercial use. Due to this lack of availability of technology and fuel, the applicability of using alternative fuels within the shipping, as well as the fishing industry, is not at the required level to be considered for global use. In addition to such difficulties, there is a paucity of information in the literature on actions taken within Scotland to further utilise alternative fuels within the fisheries sector. Interviewing stakeholders within the sector did not yield significant additional data, information or examples. There is a need to further understand whether the wider Scottish fishing sector has undertaken any steps in switching to alternative fuel, and if so what the outcomes of such steps have been. Without this information it is difficult to determine the actions taken within Scotland to reduce GHG emissions from the fisheries sector in relation to the use of alternative fuel. Furthering the understanding of steps taken within the Scottish fishing fleet would make it possible to gauge the potential for the use of alternative fuels, as well as the potential strategies for rolling such technology out into the public domain for use in other industries.

Selectivity

There is clear evidence (predominantly from the EU) that optimisation of fishing gears and the use of selective gears can reduce GHG emissions and help to mitigate the wider impacts of climate change. Despite this understanding, and the wealth of information available to show the effects of such change, there are no examples from within Scotland where fishing gears or activities have been optimised to reduce GHG emissions. There is a direct need to support research to examine the GHG emissions associated with the range of fishing measures undertaken within Scotland. If projects are ongoing within Scotland to examine how changes in gear and activity may impact GHG emissions (despite this literature review being unable to identify such projects), there is a distinct need to rigorously determine the carbon footprint of the fisheries undertaken within Scotland, and the potential impact on such emissions of changes in gear or activity. For example, determining the potential role of more selective gears, different methods of steaming during or between fishing episodes, as well as new technology that reduces the weight and drag of gears while being used are all important factors to be examined within the Scottish fishing industry.

Local markets

There is a substantial lack of information, highlighted both in the literature, but also by stakeholders, in how the use of local markets may mitigate climate change impacts of fishing. Importantly, understanding what is being done to make use of local markets for the sale of fish and shellfish within Scotland and the UK could help identify where the promotion of these routes to market could be most effective. Effectively mapping such routes and determining how they impact the creation of GHG emissions will be a vital step in understanding how best to optimise transport routes for seafood within Scotland to reduce such emissions. Achieving a widespread understanding of postharvest transport routes and the creation of GHG emissions inherent in the use of such routes will require substantially improved data collection on the fuel usage of different transport providers, the frequency of such transport and the practices utilised to undertake such transport. Such information will form a good starting point from which to effectively optimise the transport of Scottish seafood, including how best to make use of local and regional transport providers, and better understand the role of local markets in effectively reducing potential GHG emissions.

Reducing waste

There is no clear evidence that efforts to reduce gear loss, or increase the functional lifespan of fishing gear, is taking place in Scotland. However, there is further need to undertake research and analysis of the range of efforts being made currently, including what additional measures could be undertaken to support the fishing industry in Scotland in reducing waste needs. This will help increase the understanding of what is feasible for policy makers and increase the potential options available to fishermen.

Refrigerants

Refrigerants with the greatest global warming potential are regulated at a policy level within Scotland, and this represents an attempt to curb the contribution of refrigeration systems to increasing climate change. However, being able to identify where such changes in the use of refrigerants and refrigeration units occur within Scottish (and UK/EU) fisheries is extremely difficult. This is because changes in refrigeration systems within fishing businesses are ongoing, and predominantly form part of the basic business decisions being undertaken continually, weighing up the technology that is most economical/efficient against what is permitted at a policy level. As a result, such changes are rarely recorded in the literature, in public forums, and were not discussed in any depth within the stakeholder engagement in this project. Without this information it is difficult to determine further actions taken within Scotland to reduce GHG emissions from the fisheries sector in relation to the use of refrigerants.

There is a direct need to enhance the range of data being collected on the actions taken by industry to move away from prohibited refrigerants. Such information should cover upgrades to cold storage and ice making facilities on vessels and onshore facilities. This would provide policy makers verifiable data on the type of changes made as well as the reasons for making these changes such that it could inform future policy decisions with respect to refrigerants.

Stock resilience

The indicator for tracking the status of Scotland's commercial fish stocks[43] suggests that commercially fished stocks are improving overall and that there is evidence of sustainable fishing practices in many cases. However, findings of this literature review and feedback from the stakeholder consultation exercise suggest that more can be done to better manage Scotland's fish stocks and in doing so maximise their resilience to the effects of climate change. In addition, better scientific data for data deficient stocks in Scotland is needed to increase the understanding of where pressures (due to over-fishing) are potentially being experienced. Such analysis will enhance the understanding of the potential resilience of such stocks to the impacts of climate change. Findings could be acquired using modern surveys and updated stock assessments, as current data throughout the UK is considered outdated and lacking accuracy. One suggestion, highlighted during stakeholder engagement, is the need for earlier involvement of the fishing industry to understand and therefore be able to predict where potential changes in fishing activities (e.g., practices, gears) could affect the structure (and therefore resilience) of future stocks.

Consumer behaviour

Examples of actions taken to shift consumer behaviour in Scotland are available in the literature (e.g., promotion of the MSC by Marine Scotland; initiatives to educate the public about seafood sustainability; Seafood Scotland's strategy for Scotland's seafood industry). In addition, there are clear examples of how consumers favour eco-labelled 'sustainable' seafood, such as the premiums paid for eco-labelled fish and the fact that these products are less likely to be withdrawn from the shelves. There is, however, limited information available on the connection between consumer choices (e.g., purchasing eco-labelled seafood) and the associated fisheries GHG emission. Further data collection should be considered to underline the effect of changes in consumer behaviour in mitigating the impact of fisheries on climate change.

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[43] Sustainability of Fish Stocks | National Performance Framework

The gaps listed above highlight the limited information available to demonstrate progress towards mitigating the climate change related impacts of the fisheries sector within Scotland. Coordinated data collection and reporting is one strategy that could be utilised to fill many of these gaps (e.g., ensuring recipients of grants like the EMFF report their progress towards set targets). However, in order to maximise the efficacy of any data collection initiative it is useful to ensure two fundamentals are observed:

- Wherever possible, baseline values should be provided to ensure that it is possible to interpret whether actions have led to improvement or deterioration in the fisheries sectors climate related impacts. For example, it is not possible to quantify changes in fishing gear functional lifespan without baseline information on the equivalent gears expected lifespan.
- Targets, and indicators of progress towards them, should be aligned across the industry to ensure there is cohesion between the data reported. For example, if measuring effort to reduce ALDFG, should results be recorded as the number of pieces of gear removed, the volume of gear removed, or the weight of gear removed from the marine environment? One consistent metric for recording and reporting will help build the coherent database(s) necessary to effectively quantify change.

5.1 Ensure results are publicly available

Scotland and its fisheries are involved in many interventions that could reduce the sector’s impact on climate change, but the results of these actions are not publicly available. This leads to limited understanding within the industry and with policy makers on the specific reasons for, and results of, adopting such changes. More transparency in data collection, as well as in the analysis and reporting of data would substantially help demonstrate to the industry the benefits of making changes (e.g., in providing reassurance to potential users on the reliability and potential for the utilisation of alternative fuels for use in the Scottish fishing fleet), while also increasing policy makers understanding of quantifiable outcomes.

In addition, demonstrating the value and efficacy of such changes could help drive a shift to more local consumption of Scottish seafood and help strengthen the positive feedback loop between production and consumption. Consumers sufficiently informed of the impact that fishing practices are having will be more able to effectively choose products with a more benign impact, incentivising best practice in seafood production and processing.

5.2 Licensing

Hull length to width ratio plays a major role in hull resistance, and in general increasing this ratio (i.e., greater length versus width) will reduce resistance (He et al., 2018) and therefore could act as a *barrier* to further reducing the fisheries sector's climate related impacts. Yet, due to UK and Scottish licencing systems, that rely on length-based fisheries management, there is currently an incentive to keep vessels below 10 m (Davies et al., 2018). This would suggest that policy and decision makers looking to reduce fishing vessel GHG emissions should incentivise vessels with an optimised length to width ratio.

As newer technology becomes available and is adopted, particularly driven by fuel price and environmental concerns, policy makers should be looking at ways to encourage adoption of those designs/ technologies which have been developed with the purpose of reducing GHG emissions within the fisheries sector but must remain mindful of balancing opportunity and fleet capacity within effort limits.

Consequently, a further review of the current licensing system would be beneficial, to better understand the impact current licensing is having on vessel fuel efficiency and to help identify the interplay between additional factors (e.g., how vessel stability is affected by with the length to width ratio).

5.3 Other

A common theme that is borne out in the stakeholder engagement exercise, across all themes, is the need for significantly more investment from Scottish Government to facilitate the changes needed to update or improve new fishing vessels/components where the primary aim is to decrease emissions.

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7 Appendices

Appendix A Search strings

Method	Search string	Google Scholar results (2010-2021)	Titles scanned
Fossil fuel consumpt“on	"fossil ”uel" “ND "cli”ate" “ND "fishe”ies"	17400	3“
	"fossil ”uel" “ND "cli”ate" “ND "fishe”ies" “ND "Scot”and"	2,820	3“
	"fossil ”uel" “ND "cli”ate" “ND "fishe”ies" “ND”"UK"	16,300	3“
	"fossil ”uel" “ND "cli”ate" “ND "fishe”ies" “ND”"EU"	13,400	3“
	"fossil ”uel" “ND "reduced consump”ion" “ND "fishe”ies" “ND "increased effici”ncy"	47	30
	increased efficiency in fisheries “ND "reduce emiss”ons" “ND "fishe”ies"	10,300	30
	increased efficiency in fisheries “ND "reduce emiss”ons" “ND "fishe”ies" “ND”"EU"	5,690	30
	increased efficiency in fisheries “ND "reduce emiss”ons" “ND "fishe”ies" “ND”"UK"	6,370	30
	increased efficiency in fisheries “ND "reduce emiss”ons" “ND "fishe”ies" “ND "Scot”and"	913	30
	fuel efficiency “ND "fishe”ies" “ND”"EU"	17,300	30
Alternative ene“gy	"fish proces”ing" “ND "green en”rgy" “ND "Scot”and"	40	3“
	"fish proces”ing" “ND "green en”rgy" “ND "cli”ate" “ND "Scot”and"	38	3“
	"shell”ish" “ND "green en”rgy" “ND "cli”ate" “ND "Scot”and"	158	3“
	"shellfish proces”ing" “ND "green en”rgy" “ND "cli”ate" “ND "Scot”and"	1	“
	"fish proces”ing" “ND "green en”rgy" “ND”"UK"	225	30
	fish processing “ND "green en”rgy" “ND "cli”ate" “ND”"UK"	8430	3“
	"shell”ish" “ND "green en”rgy" “ND "cli”ate" “ND”"UK"	439	3“
	"shellfish proces”ing" “ND "green en”rgy" “ND "cli”ate" “ND”"UK"	3	“
	"fish proces”ing" “ND "green en”rgy" “ND”"EU"	214	3“

	"fish proces”ing" “ND "green en”rgy" “ND "cli”ate" “ND”"EU"	181	3“
	"shell”ish" “ND "green en”rgy" “ND "cli”ate" “ND”"EU"	353	3“
	"shellfish proces”ing" “ND "green en”rgy" “ND "cli”ate" “ND”"EU"	4	4
Selectiv“ty	"reduce fishing ef”ort" “ND "en”rgy"	343	3“
	"reduce fishing ef”ort" “ND "en”rgy" “ND "Scot”and"	47	3“
	"reduce fishing ef”ort" “ND "en”rgy" “ND”"UK"	180	3“
	"reduce fishing ef”ort" “ND "en”rgy" “ND”"EU"	143	3“
	"reduce fishing ef”ort" “ND "en”rgy" “ND "more effic”ent"	85	30
	fuel consumption “ND "fis”ing" “ND "re”uce"	20900	30
	fuel consumption “ND "fis”ing" “ND "re”uce" “ND "Scot”and"	14500	30
	fuel consumption “ND "fis”ing" “ND "re”uce" “ND”"UK"	21100	30
	fuel consumption “ND "fis”ing" “ND "re”uce" “ND”"EU"	18200	3“
	"reduce fishing ef”ort" “ND "environme”tal" “ND "selec”ive"	254	3“
	"reduce fishing ef”ort" “ND "environme”tal" “ND "Scot”and"	91	3“
	"reduce fishing ef”ort" “ND "environme”tal" “ND”"UK"	381	3“
	"reduce fishing ef”ort" “ND "environme”tal" “ND”"EU"	280	3“
	"reduce morta”ity" “ND "fis”ery" “ND "non target spe”ies"	284	3“
	"reduce morta”ity" “ND "fis”ery" “ND "non target spe”ies" “ND "Scot”and"	23	2“
	"reduce morta”ity" “ND "fis”ery" “ND "non target spe”ies" “ND”"UK"	108	3“
	"reduce morta”ity" “ND "fis”ery" “ND "non target spe”ies" “ND”"EU"	60	30
Local mark“ts	"l”cal" “ND "”ish" “ND "greenhouse g”ses" “ND "Scot”and"	4580	3“
	"l”cal" “ND "”ish" “ND "greenhouse g”ses" “ND”"UK"	18800	3“
	"cons”mer" “ND "locally sou”ced" “ND "”ish"	3630	3“
	"cons”mer" “ND "locally sou”ced" “ND "”ish" “ND "Scot”and"	504	30
Reducing wa“te	"reduce w”ste" “ND "fis”ery"	1690	3“
	"reduce w”ste" “ND "fis”ery" “ND "greenhouse”gas"	598	3“
	"reduce w”ste" “ND "fis”ery" “ND "marine li”ter"	94	3“
	"reduce gear ”oss" “ND "fis”ery"	37	3“
	"reduce gear ”oss" “ND "fis”ery" “ND "greenhouse”gas"	1	“
	"reduce gear ”oss" “ND "fis”ery" “ND "marine li”ter"	12	1“
	"reduce w”ste" “ND "fis”ery" “ND "Scot”and"	158	3“

	"reduce w”ste" “ND "fis”ery" “ND”"UK"	899	3“
	"reduce w”ste" “ND "fis”ery" “ND”"EU"	720	3“
	"reduce marine li”ter" “ND "fis”ery"	174	3“
	"reduce marine li”ter" “ND "fis”ery" “ND "Scot”and"	51	3“
	"reduce marine li”ter" “ND "fis”ery" “ND”"EU"	141	3“
	"reduce marine li”ter" “ND "fis”ery" “ND”"UK"	111	30
Refrigera“ts	"refrige”ant" “ND "greenhouse gas emiss”ons" “ND "fis”ery"	238	3“
	"refrige”ant" “ND "greenhouse gas emiss”ons" “ND "fis”ery" “ND "Scot”and"	27	2“
	"refrige”ant" “ND "emission ”ate" “ND "fishing ve”sel"	5	“
	"refrige”ant" “ND "emission ”ate" “ND "fishing ve”sel" “ND "amm”nia"	5	“
	"refrige”ant" “ND "emission ”ate" “ND "fishing ve”sel" “ND "Scot”and"	1	1
Stock resilie“ce	"stock resili”nce" “nd "fis”ery" “nd "climate ch”nge" “ND "q”ota"	45	3“
	"stock resili”nce" “nd "fis”ery" “nd "climate ch”nge" “ND "q”ota" “ND "Scot”and"	5	“
	"stock resili”nce" “nd "fis”ery" “nd "climate ch”nge" “ND "q”ota" “ND”"UK"	16	1“
	"stock resili”nce" “nd "fis”ery" “nd”"EU"	64	30
Consumer behavi“ur	"consumer behav”our" “ND "fis”ery" “nd ”MSY"	53	3“
	"consumer behav”our" “ND "fis”ery" “nd ”MSY" “nd "Scot”and"	7	“
	"”ish" “ND "cons”mer" “nd "reduce food m”les"	214	3“
	"”ish" “ND "cons”mer" “nd "reduce food m”les" “ND "Scot”and"	33	3“
	"sustainably sourced ”ish" “ND "cons”mer" “ND "interven”ion"	42	30

Appendix B Typology

Location/ geographic relevance	Actions taken	Results	Strengths	Weaknesses	Reference
Method: Reducing vessel fuel consumption					
Intervention: Propulsion systems (Engines)					
UK (England)	Seven EMFF projects funding the replacement or modernisation of old engines in English fishing vessels.	In one case, there was a reported reduction in fuel consumption of 30 to 70 litres per week (representing between 15 and 32 % of fuel used). Taking the average value, this represents an annual reduction of around 7 tonnes of CO2e from this one project, or an ongoing annual reduction of 4.81kg CO_2e for every £1 of EMFF funding.	• Reengining is relatively straightforward; • Recording results is relatively straightforward; and • The initial cost is relatively low.	• Only one of the seven projects recorded and presented results; and • Relatively low uptake - only seven vessels in the English fleet were funded for reengining.	Owen et al., 2019 (added after the systematic review)
EU (not specified)	Hybrid diesel electric propulsion system trial	Reduce fuel consumption of up to 10 % achieved under laboratory conditions	• Reduced weight due to hybrid propulsion system;	• Results only available for trials under laboratory conditions (i.e., no	Notti and Sala, 2012

Location/ geographic relevance	Actions taken	Results	Strengths	Weaknesses	Reference
			• Noise, pollution and vibration reduced; and • Weight on board can be better distributed for stability.	practical trails).	
Intervention: Propulsion systems (gearbox and propeller)					
UK (England)	Propeller modifications undertaken with EMFF funding, £29,262 received in funding across 6 projects.	None reported	• N/A	• No results reported	Owen et al., 2019 (added after the systematic review)
EU (Italy)	• Two speed reduction gear boxes used to perform each fishing phase, in an effort not to overload the main engine and saving fuel. • Engine and propeller were coordinated	A Bollard pull tests demonstrated that: • With the ducted propeller, thrust was increased up to 25 %, compared with a standard propeller of equivalent and pitch and diameter.	• Observed fuel saving; • Changes made are relatively easy to implement; • The changes can be made in both older vessels and new ones; • Possibility for reducing weight, and noise pollution.	N/A	Notti and Sala, 2012

Location/ geographic relevance	Actions taken	Results	Strengths	Weaknesses	Reference
	through the reduction gear to optimise conditions for steaming and trawling; and • A ducted propeller was used to increase thrust, replacing fixed pitch propeller.	• A 15/20 % reduction in fuel consumption was observed, due to less thrust require for same engine power.			
Intervention: Hull design					
UK (England)	Two EMFF projects received funding (£42,300 across both projects) for bulbous bow hull modification to improve fuel efficiency.	Resulted in a reduction in fuel consumption of around 5 %. This is an estimated reduction of 13,152 litres annually, equivalent to an annual saving of 35 tonnes of CO_2e or 1.67kg CO2e for every £1 of EMFF funding .	N/A	• Beneficiaries confirmed that as a result of the modifications they are now able to fish in conditions where they couldn't previously. This may therefore have led to increased fishing effort, negating the	Owen et al., 2019 (added after the systematic review)

Location/ geographic relevance	Actions taken	Results	Strengths	Weaknesses	Reference
				fuel saving made. • Under some conditions (e.g., certain speeds) bulbous bows can increase resistance and fuel use.	
Intervention: Antifouling					
UK (England)	Three EMFF projects received funding (£7,309 across all projects) for antifouling to improve fuel efficiency.	None reported	N/A	N/A	Owen et al., 2019 (added after the systematic review)

Location/ geographic relevance	Actions taken	Results	Strengths	Weaknesses	Reference
Method: Selectivity					
Intervention: Reduced fishing effort (time at sea)					
UK (Scotland)	Real time bycatch avoidance APP that uses mapping and fisher reporting.	Inconclusive	• Realtime reporting by fishers could help fishers avoid bycatch hotspot areas.	Requires fishers to share catch data, which they are not always keen to do;	Marshall et al., 2021 (added after the

Location/ geographic relevance	Actions taken	Results	Strengths	Weaknesses	Reference
	It is called BATmap			Difficult in practise to define species hot-spots.	systematic review)
UK (England)	EMFF projects funded to improve selectivity in nets and pots via escape hatches.	Unwanted catches with new more selective pots were reduced by 10-15 %.	• No reported decrease in landings with greater selectivity; and • Allows smaller individuals of the target species to grow larger, leading to expected stock fecundity.	No clear pathway to reduced fuel consumption as a result in increased selectivity.	Owen et al., 2019 (added after the systematic review)
EU (not specified)	Modelling of real time reporting of areas with high abundance of non-target species, leading to shorter area closures compared to traditional area closures (enacted when bycatch is over a certain % of catch).	Some potential utility in reducing bycatch	• Quick and adaptable to real time changes in species presence and abundance; • Could supplement selective fishing gear and allows fishermen to spend less effort in areas with high abundance of unwanted species.	Difficult in practise to define species hot-spots.	Eliasen and Bichel 2016
Intervention: Reduced fuel consumption while fishing					
EU (Denmark)	New trawl system - using	Trials showed:	Multiple benefits demonstrated	Multiple parameters	Hansen and

Location/ geographic relevance	Actions taken	Results	Strengths	Weaknesses	Reference
	larger and lighter gear in the cod fishery. Optimizing the trawl and trawl doors. The 12 mm steel trawl warps were replaced with warps of 10 mm Dyneema® and the rest of the net, excluding the codend, was made of 1.4 mm Dyneema®. This was done to reduce drag.	• A reduction in fuel use by around 40 % of per kg of cod caught; • Increased catch per unit effort; and • Reduced bottom contact.	during the trial (e.g., increased fuel efficiency, increased catch per unit effort, and reduced bottom contact).	were altered when trialling this new trawl rig, so exact causes of fuel savings are unknown.	Tørring, 2012
UK (England)	Western Fish Producers Organisation (WFPO) recently conducted a trial with Sumwings, which replaced traditional otter doors on a beam trawler out of Brixham, in the south east of England.	The WFPO trial found: • a 42 % reduction in fuel use (with ongoing use, the average reported fuel saving was approximately 30 %); and • Reduced interaction with the seabed (by up to 84 %) leading to a 69 % drop in discards of benthic species.	"Taking the average fuel saving of 90 litres per hour seen during the trial and an average towing time of 18 hrs per day, the potential saving totals 1,620 litres per day. Given a fuel price of £0.60 per litre the saving per day is £972.00. On average, if a SW beam trawler carries out 200	N/A	Caslake 2022 (added after the systematic review)

Location/ geographic relevance	Actions taken	Results	Strengths	Weaknesses	Reference
			fishing days per year, the potential saving per year is £194,400. The cost of a set of two Sumwing beams is approximately £30,000 more than a set of traditional beams. The payback period to cover the additional cost of the Sumwing beams with the fuel saved equates to 31 days fishing" (Caslake 2022). The Decreased interaction with the seafloor doubled the expected lifespan of the fishing gear.		
EU (Netherlands)	Pulse trawling used in place of a tickler chain beam trawl.	"pulse trawls had fewer fish discards (57 %, $p <$ 0.0001), including 62 % undersized plaice (*Pleuronectes platessa* L.) ($p <$	• Fewer discards; • Reduced seabed interaction; and • Reduced fuel consumption.	• Possible spinal damage to cod; • issues of animal welfare (low social	Van Marlen et al., 2014

Location/ geographic relevance	Actions taken	Results	Strengths	Weaknesses	Reference
		0.0001), and 80 % discarded weight of benthic invertebrates (p = 0.0198) per hectare. The pulse fishing technique resulted in a lower fuel consumption (37–49 %), and consequently in spite of lower landings net revenues were higher"		acceptance); and • the injury and mortality of non-target species.	
Turkey	Experimenting with different sledge designs in sea snail beam trawl fisheries in the southern Black Sea, Turkey.	Determined that the M-1 (sledge type shoe with a 5mm claw) modified design was the "most appropriate gear to reduce resistance and fuel consumption on both sea bottoms at constant rpm and towing speed".	Relatively minimal modification needed- easy to implement and in doing so reduce resistance, seabed interaction and fuel consumption.	N/A	Kaykaç et al., 2017
Method: Reducing waste					
Intervention: Reduced loss of functional fishing gear					
UK (England)	the Sumwing trial by the WFPO.	84 % reduction in gear/seabed interaction, leading to	Multiple benefits of the new Sumwing trawl gear, including	N/A	Caslake, 2022

Location/ geographic relevance	Actions taken	Results	Strengths	Weaknesses	Reference
		doubling of the gear's operational life expectancy.	reduced seafloor interaction.		(added after the systematic review)
EU (Netherlands)	A mobile app to "reduce damaged and lost fishing gear". Gives location of set gill nets to help trawlers avoid them and causing damage. Gill net fishermen also supposed to set nets with space for trawlers to fish between them.	Since the app was introduced damage to gill nets or loss of nets has "declined substantially".	Decline in the damage and loss of static nets observed in practical trails	Requires fishers to share the location of their actively fishing gear.	Mengo, 2017
Norway	• The Directorate of Fisheries carries out an annual retrieval operation to recover lost gill nets; • There are facilities to report location of fishing gear when set to improve chances of	There has been an increase in the reporting of lost gear which otherwise would not have been reported, improving the chance of successful recovery.	Vessels can see and detect fishing gear in the water to avoid gear conflict and the possible relocation (leading to loss) or damage of the set gear.	Requires fishers to share the location of their actively fishing gear.	Mengo, 2017; Langedal et al., 2020

Location/ geographic relevance	Actions taken	Results	Strengths	Weaknesses	Reference
	recovery if lost; and • Identification on gear discourages abandoning damaged gear or dumping fishing equipment at sea.				
Intervention: Reduce ALDFG					
UK (Scotland)	Fishing for Litter project, which facilitates the collection and removal of waste from fishing vessels. Coordinated in Scotland by KIMO UK. The project spans Europe, but in Scotland, 285 vessels and 20 ports are participating.	1800 tonnes of rubbish removed from the ocean.	Incentivises best practice in gear disposal through improved awareness, facilities and logistics.	Not strictly aimed at reducing fishing gear loss.	OSPAR, 2020
EU (Netherlands)	'Green Deal Fishery for a Clean Sea' - "the fishing sector, fishing harbours,	Multi-sector collaboration to “decrease the amount of marine litter from the	N/A	N/A	Mengo, 2017

Location/ geographic relevance	Actions taken	Results	Strengths	Weaknesses	Reference
	waste organisations, NGO's and the ministry, work together to decrease the amount of marine litter from the fishing sector and to increase the recycling of the fishing waste collected."	fishing sector and to increase the recycling of the fishing waste collected".			
EU (Spain)	Pilot projects to improve waste management on vessels and in harbours. Installing waste containers on vessels; installing recycling points in fishing and navigation docks; research on potential markets for fishing industry waste.	N/A	The easy access for vessels to participate should makes them more likely to.	N/A	Mengo, 2017
EU (Sweden)	'No-Special-Fee' system. Commercial fishermen pay a port fee and can	N/A	The easy access for vessels to participate should makes them more likely to.	N/A	Mengo, 2017

Location/ geographic relevance	Actions taken	Results	Strengths	Weaknesses	Reference
	dispose of waste in port.				
	'Keep the Sea Clean' project in Bohuslän facilitates the collection and recycling of fishing gear and marine litter.	N/A	The easy access for vessels to participate should makes them more likely to.	N/A	Mengo, 2017
Norway	2013 waste strategy - "marine litter caught in fishing gear can be handed in with no fee". Fee is incorporated into port charge so not dependent on amount of waste landed. Fishing gear can be recycled.	N/A	N/A	N/A	Mengo, 2017

Location/ geographic relevance	Actions taken	Results	Strengths	Weaknesses	Reference
Method: Stock resilience					
Intervention: Harvest strategy					
UK (Scotland)	Measures to improve stock status.	The Scottish Marine Assessment	• Improved stock status in terms of	SSB is at, or below, $B_{trigger}$ for 44 % of	Marine Scotland, 2020

Location/ geographic relevance	Actions taken	Results	Strengths	Weaknesses	Reference
		2020, compared 'key stocks' and found that the percentage of stocks fished at or below F_{MSY} has increased from 46 % in 2016, to 54 % in 2018 (Marine Scotland 2020). This suggests that management measures have been effective within these fisheries.	harvest rates and biomass indicators. • • Overall, Scotland compares favourably to the EU, where 74 % of species are fished above FMSY and 49 % of species are outside of safe biological limits (B < 0.5 B_{MSY}) (Froese et al., 2018).	the eight most valuable fish species to Scotland (total landings value), and a further 22 % that are above $B_{trigger}$ are fished above F_{MSY}	(added after the systematic review)
Intervention: Exploitation pattern					
UK (Scotland)	A prohibition on landing female lobsters with a carapace length over 145 mm (except the Orkney Islands and	N/A	As a regulatory instrument this should help increase the number of large fecund individuals, which produce a disproportiona	Orkney Islands and Shetland Islands excluded from these measures.	https://www.legislation.gov.uk/ssi/2017/455/contents/made (added after the systematic review)

Location/ geographic relevance	Actions taken	Results	Strengths	Weaknesses	Reference
	Shetland Islands)		te quantity of high-quality eggs when compared to smaller sexually mature individuals.		
UK (England and Wales)	Prohibition on landing berried (egg bearing) female lobsters; and the adoption of a Maximum Landing size for lobsters.	N/A	As a regulatory instrument this should help increase the number of large fecund individuals, which produce a disproportionate quantity of high-quality eggs when compared to smaller sexually mature individuals.	N/A	Woolmer et al., 2010
UK (Northern Ireland)	Irish Sea Nephrops fishery - Escape panel in trawl nets to allow escape of juvenile haddock and whiting. Fitted	Reduce catch of juvenile haddock and whiting without loss of Nephrops catch: "16 comparative hauls this net	No reduction in target species catch.	N/A	Briggs, 2010

Location/ geographic relevance	Actions taken	Results	Strengths	Weaknesses	Reference
	a 120mm square mesh escape panel in the trawl gear.	configuration allowed 54 % of juvenile haddock and 65 % of juvenile whiting to escape from the net with no loss in Nephrops catch"			
EU (not specified) Intervention:	Nephrops fishery: a square mesh panel - "300 mm window is placed at the top section at about 3–6 m from the cod line". This is done to reduce the bycatch of roundfish in Nephrops trawls.	"both reduction of cod catches and the estimated proportion of cod that contact the window were >85 %"	The use of the window instead of a grid avoids the loss of marketable lobster.	Loss of other commercial species, such as plaice. Window is placed far back so further escape may be possible during haul back.	Madsen et al., 2010
Intervention: Refrigerants					
UK (not specified)	Since 2020, fluorinated GHGs with a GWP greater than 2500 have been	N/A	As a statutory instrument this should act to reduce the use of refrigerants	Progress results are not available	https://www.sepa.org.uk/regulations/climate-change/fgases-and-ods/

Location/ geographic relevance	Actions taken	Results	Strengths	Weaknesses	Reference
	prohibited in Scotland for use in servicing or refilling refrigeration systems		with a very high GWP. However, progress results are not available.		(added after the systematic review)
Intervention: Alternative energy					
UK (Wales)	Milford Haven industrial site: modelling a smart energy cluster that can manage energy production more effectively, using energy from local photovoltaics and a solar farm.	Model showing that the it could be possible to: • Provide "cost advantages for industries and stakeholders and can provide a more competitive integration of small and medium energy businesses within the wholesale energy market"; • Provide green energy to the fish industries and local	N/A	Relies on solar energy, so less reliable in winter, when output is expected to dip below demand.	Alzahrani et al., 2020; Petri et al., 2020.

Location/ geographic relevance	Actions taken	Results	Strengths	Weaknesses	Reference
		community; and Sell excess energy back to the national grid.			
EU (Finland)	Production of biodiesel from fish waste from fish processing. The biodiesel is used in fish farm operations and local buses.	"plant produces approximately 400 litres of fish biodiesel a day. In a year, the plant can turn 15–20 m3 of fish oil into biodiesel."	Cuts operational costs and produces a close to carbon neutral fuel.	It has not been implemented for commercial sale yet as biodiesel is taxed in the same way as fossil fuels.	Mikkola and Randall, 2016
EU (Denmark)	Aquapri - aquaculture and fish processing plant design and implementation of a bespoke ventilation system to reuse waste energy.	N/A	The return on investment was expected to take 2.5 years	• Took 9 months to complete from start to finish (longer than expected); and Large initial outlay.	Solberg et al., 2016
Local markets				•	
N/A	N/A	N/A	N/A	• N/A	N/A

Location/ geographic relevance	Actions taken	Results	Strengths	Weaknesses	Reference
Consumer behaviour					
UK (Scotland)	Promotion of the MSC by Marine Scotland	N/A	This endorsement could be seen to build consumer trust in the eco-label.	• N/A	https://www.gov.scot/policies/sea-fisheries/fish-stocks/ (added after the systematic review)
UK (Scotland)	Work to educate the public about seafood sustainability by Open Seas	N/A	N/A	• N/A	https://www.openseas.org.uk/ (added after the systematic review)
UK (Scotland)	Seafood Scotland's strategy for Scotland's seafood industry, which aims (amongst other things) to "use standards and accreditation to support marketing and improve	N/A	N/A	• N/A	http://seafoodscotland.org/wp-content/uploads/2019/05/Changing-Tides-_FINAL_PAGES.pdf (added after the systematic review)

Location/ geographic relevance	Actions taken	Results	Strengths	Weaknesses	Reference
	business performance"				
UK (not specified)	The Marine Conservation Society's Good Fish Guide provides information to help consumers understand which species and stocks are sustainable and which are not. Species are rated based on stock status, where it was caught or farmed and how.	N/A	There is accessible information granulated to a stock level.	• N/A	https://www.mcsuk.org/goodfishguide/?gclid=CjwKCAiA6Y2QBhAtEiwAGHybPcj_v_BeH_-IrQyj3hlFcknQDgo_KtpKOFNfNFMf9YuCGsrkP8S1DBoCKfUQAvD_BwE (added after the systematic review)

Appendix C List of Stakeholders

1. Scottish Association of Fish Producers Organisations
2. Fife Fishermen’s Association
3. Fishing Vessel Agents & Owners Association (Scotland) Limited
4. Regional Inshore Fisheries Groups (RIFG)
5. Clyde Fishermen’s Association
6. Scottish Fishermen’s Federation
7. Orkney Fisheries Association
8. Mallaig and North-West Fishermen’s Association Limited
9. Anglo-Scottish Fishermen’s Association
10. Shetland Fishermen’s Association
11. Regional Inshore Fisheries Group (RIFG)
12. Communities Inshore Fisheries Alliance
13. Seafood Scotland
14. Marine Alliance for Science and Technology for Scotland (MASTS)
15. Scottish Environment Link
16. Scottish Pelagic Fishermen’s Association Limited
17. Scottish Creel Fishermen’s Federation
18. Scottish White Fish Producers’ Association Limited
19. Seafish

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